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Physical Data Collection for Lock Wall Deterioration

Robert C. Patev, Paul F. Mlakar, and Larry M. Bryant

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Physical Data Collection for Lock Wall Deterioration

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Final report

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Preface

The Waterways Experiment Station of the U.S. Army Engineer Research and Development Center (ERDC) was tasked by the Engineering Work Group for the Upper Mississippi River-Illinois Waterways Navigation Study to collect physical data for use in a reliability model for the deterioration of concrete in lock walls due to freeze-thaw and abrasion. This work effort was accomplished by Mr. Robert C. Patev, formerly of the Computer-Aided Engineering Division (CAED), Information Technology Laboratory (ITL), ERDC, with assistance from Dr. Mary Ann Leggett, CAED, ITL, ERDC, and Mr. Ron Wooley, Navigation Branch (NB), Waterways Division (WD), Hydraulics Laboratory (now the Coastal and Hydraulics Laboratory), ERDC. The report was prepared and written by Mr. Patev and Mr. Paul F. Mlakar and Mr. Larry M. Bryant, formerly of JAYCOR. The work was performed under the general supervision of Mr. H. Wayne Jones, Chief, CAED, ITL, and Dr. N. Radhakrishnan, former Director, ITL. Mr. Timothy D. Ables is Acting Director, ITL.

At the time of publication of this report, Director of ERDC was Dr. James R. Houston. Commander was COL James S. Weller, EN.

Conversion Factors, Non-SI to SI Units of Measurement

Non-SI units of measurement used in this report can be converted to SI units by applying the following factors as follows:

Multiply	By	To Obtain
feet	0.3048	meters
inches	0.0254	millimeters
miles (U.S. statute)	1.609347	kilometers

1 Introduction

The collection of physical data from lock chambers was required to properly develop the concrete deterioration model used for the Upper Mississippi River–Illinois Waterways Navigation Study (UMR-IWW). Statistical data needed for the model were collected from the measurements of concrete loss from four lock chambers and the time-lapse videotape monitoring of three lock chambers. Each item was crucial in developing the proper constraints to be used in the deterioration model.

Since the loss of concrete in lock chambers has not been typically measured during concrete inspections, it was necessary to measure the amount of loss attributable to freeze-thaw and abrasion. These measurements of loss would be the basis for developing a function that could predict the shape of concrete loss centered at the elevation of maximum loss. This loss of concrete from lock walls creates uneven surfaces that cause the exposure of embedded metals such as line hooks, check posts, or ladders that may cause barges to be impeded in transiting the lock or during lock filling or emptying.

The time-lapse videotape monitoring assisted with determining statistical values of previously unknown or estimated variables that were used in the UMR-IWW model. Since the field collection of physical data is often an expensive and time-consuming task, time-lapse monitoring was implemented to assist with physically cataloging hours of field data at a minimal cost. The collected data characterized the values for the number of impacts on lock walls that occur during a lockage, the velocity of a barge in different locations in a lock chamber, and the fluctuation of chamber pools with time. The data were used as a basis in the successful implementation of the model since the constraints of the model were parameters that were directly input as variables or constants in the probabilistic concrete deterioration model.

2 Vertical Surface Losses in Lock Chambers

Introduction

Loss of concrete from lock walls may delay tows in transiting the lock by creating uneven surfaces that may cause a barge to "hangup" during lock filling or emptying. This effect may be more significant than any structural deficiencies and historically is often the primary motivation for resurfacing of lock walls. A model for assessing lock wall vertical surfaces for this operational problem is developed in the following paragraphs.

Previous Study

The basic model for vertical surfaces was developed in a previous study.[1] In that study, the barge geometry was totally characterized by the radius, R_1, at the barge corner, which is assumed to be small relative to the concavity of the lock wall. The shape of the deteriorated surface was approximated by a parabola with zero concrete loss near the top and bottom of the lock wall with maximum loss near midpool, as illustrated in Figure 1. This deterioration function was

$$x = \alpha y^n \tag{1}$$

where:

x = horizontal component of concrete loss

α = constant reflecting *magnitude* of concrete loss

y = vertical distance measured from center of surface

n = exponent reflecting the *shape* (concavity) of the loss

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[1] Larry M. Bryant and Paul F. Mlakar. (1991). "Predicting concrete service life in cases of deterioration due to freezing and thawing," Technical Report REMR-CS-35, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

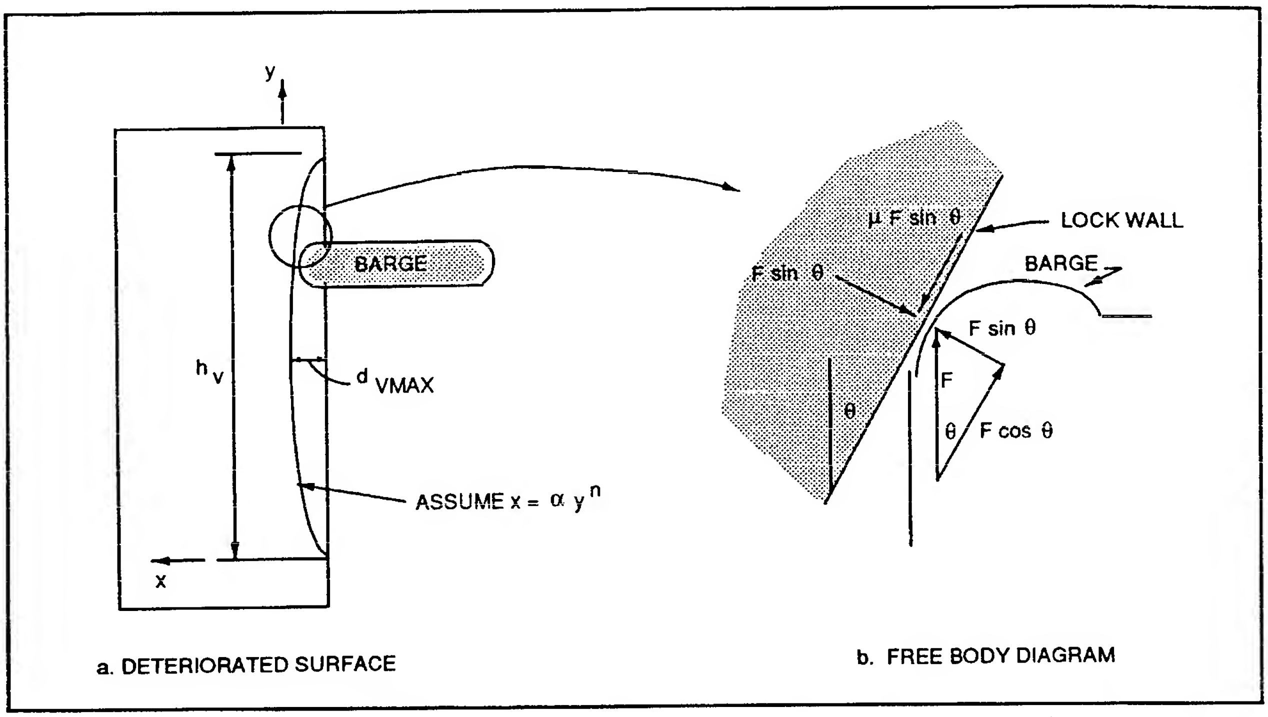

Figure 1. Vertical surfaces model (from Bryant and Mlakar 1991)[1]

For a symmetric deterioration function with a maximum concrete loss of d_{vmax} and a total height of deteriorated surface of h_v , then

$$x = \frac{d_{vmax}}{\left(\frac{h_v}{2}\right)^n} \times y^n \tag{2}$$

With these geometric parameters, the model considered the frictional force developed between the rounded corner of the barge and the concave surface of the deteriorated lock wall.

For a resultant vertical force, F, on the barge due to filling of the chamber, the equal and opposite normal forces developed between the barge and the lock wall are $F(\sin\theta)$, where θ is the angle of the lock wall surface with the vertical. The frictional force developed is thus $\mu F(\sin\theta)$, where μ is the apparent coefficient of friction between the barge and the lock wall. If this friction force is greater than the collinear acting force, $F(\cos\theta)$, the barge will hang up on the wall, creating an operational problem. Therefore, factor of safety against this operational problem may be defined as

$$F = \frac{F(\cos\theta)}{\mu F(\sin\theta)} = \frac{1}{\mu(\tan\theta)} \tag{3}$$

[1] Ibid.

where

$$tan\theta = ny^{n-1}\,\frac{d_{v\,max}}{h_v^n} \tag{4}$$

The minimum factor of safety occurs for maximum angle, θ, which occurs for $y = h_v/2$, i.e.,

$$F = \frac{h_v}{2n\mu\, d_{v\,max}} \tag{5}$$

This earlier model proved useful and indicated promise with subsequent improvement. In fact, a recommendation from the previous study by Bryant and Mlakar was made to refine the (dimensional stability) model for the lock wall limit state by investigating and calibrating to more field structures. This recommendation was addressed in the development of the refined model used in this study.

Refinement of Model

In the current study, the model has been improved based on a more extensive investigation of actual concrete loss for lock wall vertical surfaces. Using detailed measurements from two locks, the description of the concrete loss (as a function of wall elevation) has been further generalized. The measurements from these two locks were scrutinized to determine any underlying pattern of deterioration that could be generalized for other locations. From this investigation, several analytical functions for the loss function were considered and evaluated using linear regression. The most promising of these functions, that also could be rationally explained from physical phenomena, was generalized for use in the loss model.

Loss Measurements Data

Measurements of the vertical faces of lock chambers were made and evaluated to examine the patterns of deterioration of lock wall concrete. The measurements were taken at locks on different river systems and under distinct winter operation patterns to investigate the range of deterioration that may occur. The locks selected for the study were Lockport Lock and Dam on the Chicago Ship and Sanitary Canal, Point Marion Lock and Dam on the Monongahela River, and Locks and Dams 13 and 15 on the Mississippi River (Appendixes A, B, C, and D, respectively). Two types of deterioration patterns were exhibited at these locks. They were loss concentrated around the upper pool region and evenly distributed losses around the lower pool area.

The loss around upper pool levels was illustrated well at Lockport Lock and Dam and Point Marion Lock and Dam. This loss pattern can be

attributed to the fact that the locks are in service year round at times when freeze-thaw and abrasion can occur simultaneously. The loss around lower pool is characterized by Locks and Dams 13 and 15. This pattern is attributable to lack of operation during the winter months. The locks are generally out of service from late December to early March, and their chamber pools are left at lower pool elevations. The goal of these measurements was to get an overall picture of loss in a range of lock chambers to assist with developing a function to closely represent the true loss. This function will be used directly in the model to determine concrete deterioration of lock walls due to freeze-thaw and abrasion.

Lockport Lock - Chicago Ship and Sanitary Canal

Lockport Lock was constructed in 1933 and exhibits severe loss of concrete from the vertical surfaces. The lock hardware was rehabilitated in July 1984, and the lock walls were scheduled for resurfacing in July 1995. The lock wall vertical geometry was measured in 1984 when the lock was completely dewatered. These measurements were made using a plumb line along both the land wall (even monolith numbers) and river wall (odd monolith numbers). Data were taken at 1-ft increments in elevation at centers of selected monoliths and at or near selected joints. Similar measurements were made in January 1993 at the same locations as in 1984 to provide additional loss data and an indication of the time dependence of the concrete loss.

Typically, the deterioration along the land wall is generally worse than that along the river wall. The higher losses on the land wall are due to increased impacts resulting from the location of the floating mooring bits which influence tow operator locking preferences for entry and exit at the lock. Maximum losses were about 10 in. in 1984 and about 11 in. in 1993 in the land wall. Maximum river wall losses were about 4 and 5 in., respectively, in 1984 and 1993. Losses are quite uneven with elevation and between monoliths. The most severe losses in most monoliths occur near upper pool (el 578 ft)[1] in most cases.

All of the data from both sets of measurements are presented in Figures 2 through 9. The losses measured in 1984 at land wall monoliths are plotted versus elevation in Figure 2. Measurements of concrete loss along river wall monoliths in 1984 are shown in Figure 3. Figures 4 and 5 present 1984 loss measurements at joints along the land wall and river wall, respectively. Similar measurements made in 1993 are presented in Figures 6 through 9 for land wall and river wall monoliths and joints.

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[1] Unless otherwise stated, all elevations (el) are stated in feet as referred to in National Geodetic Vertical Datum (NGVD) of 1929.

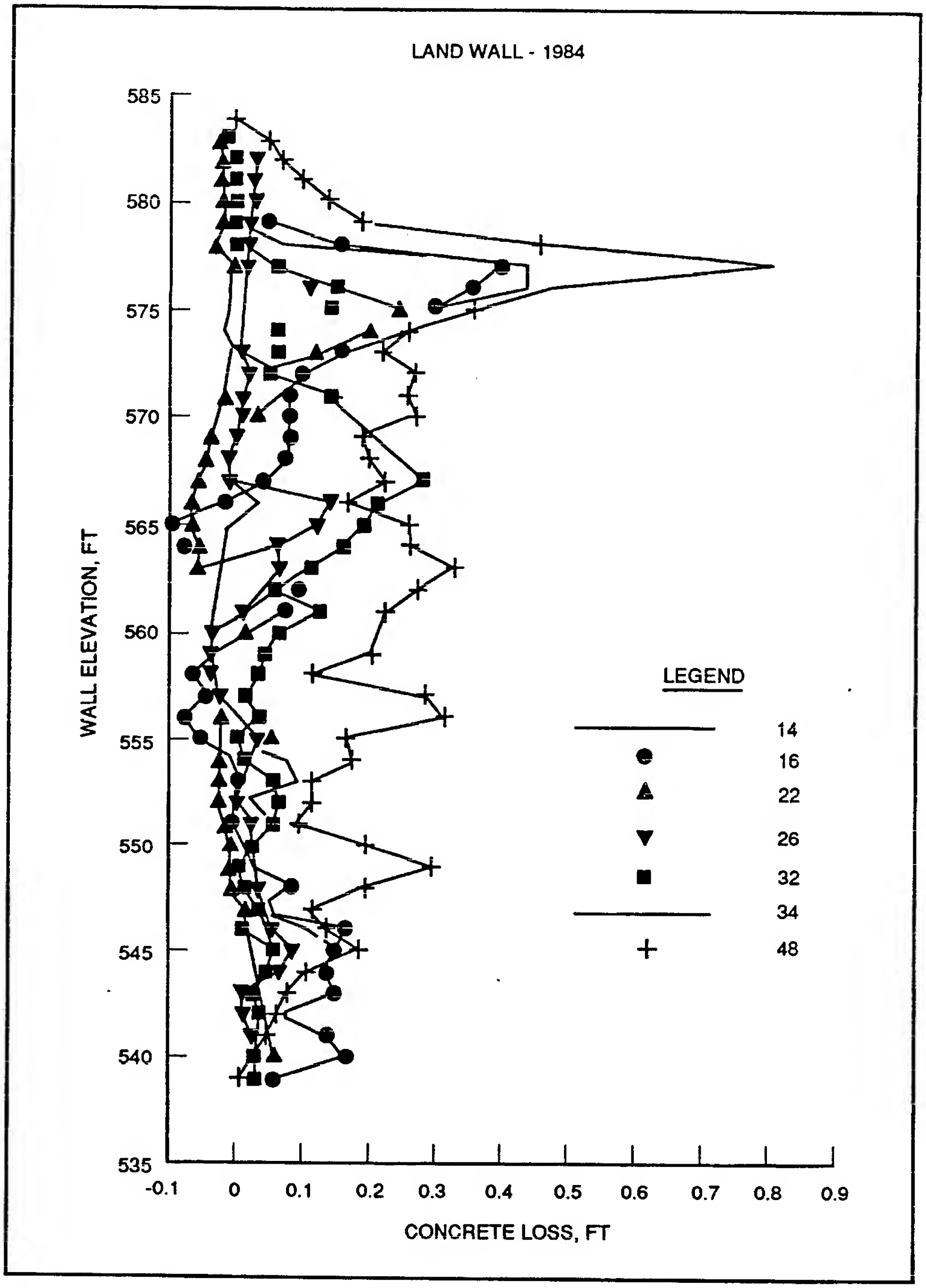

Figure 2. Loss measurements for Lockport land wall monoliths, 1984

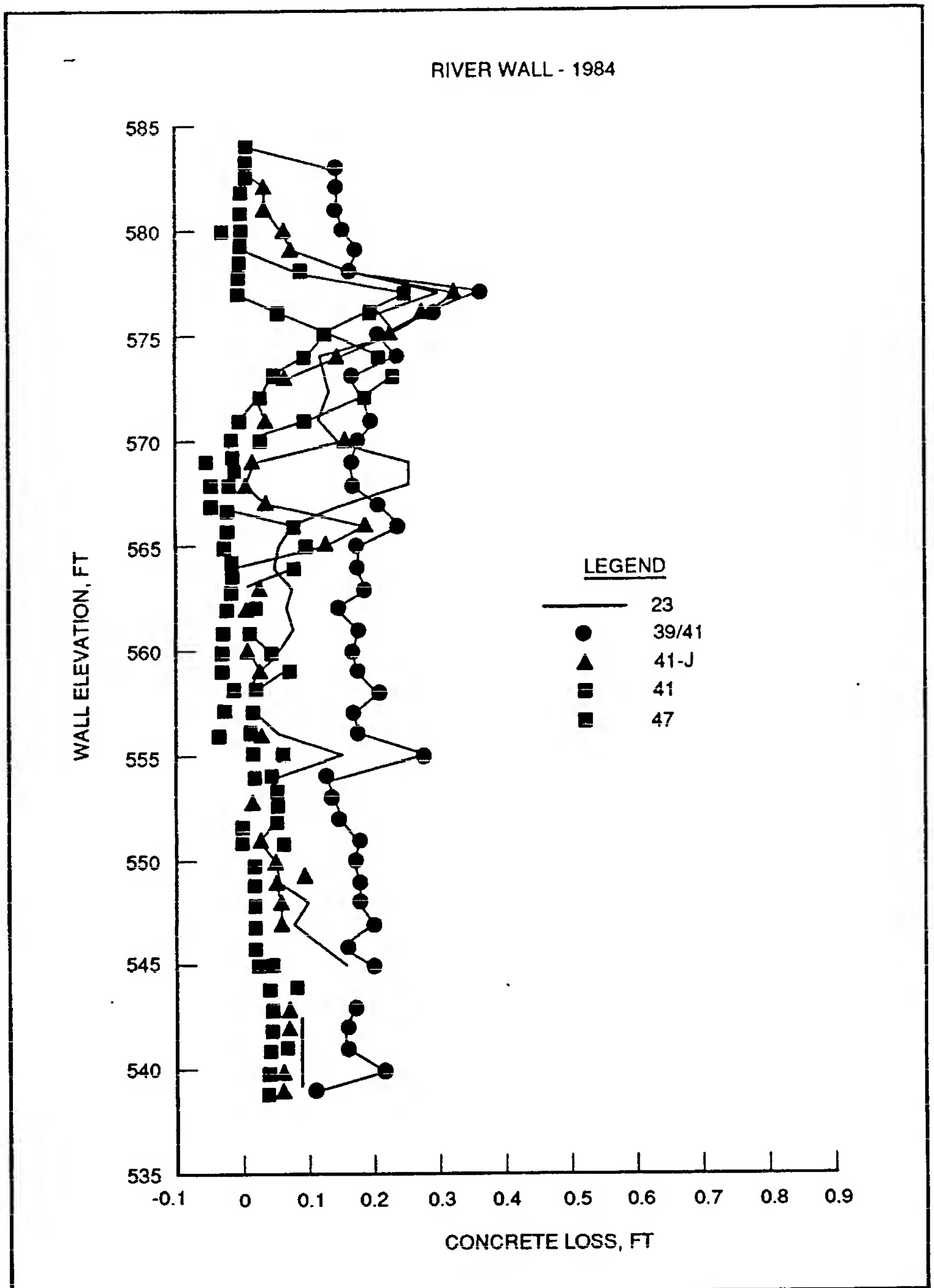

Figure 3. Loss measurements for Lockport river wall monoliths, 1984

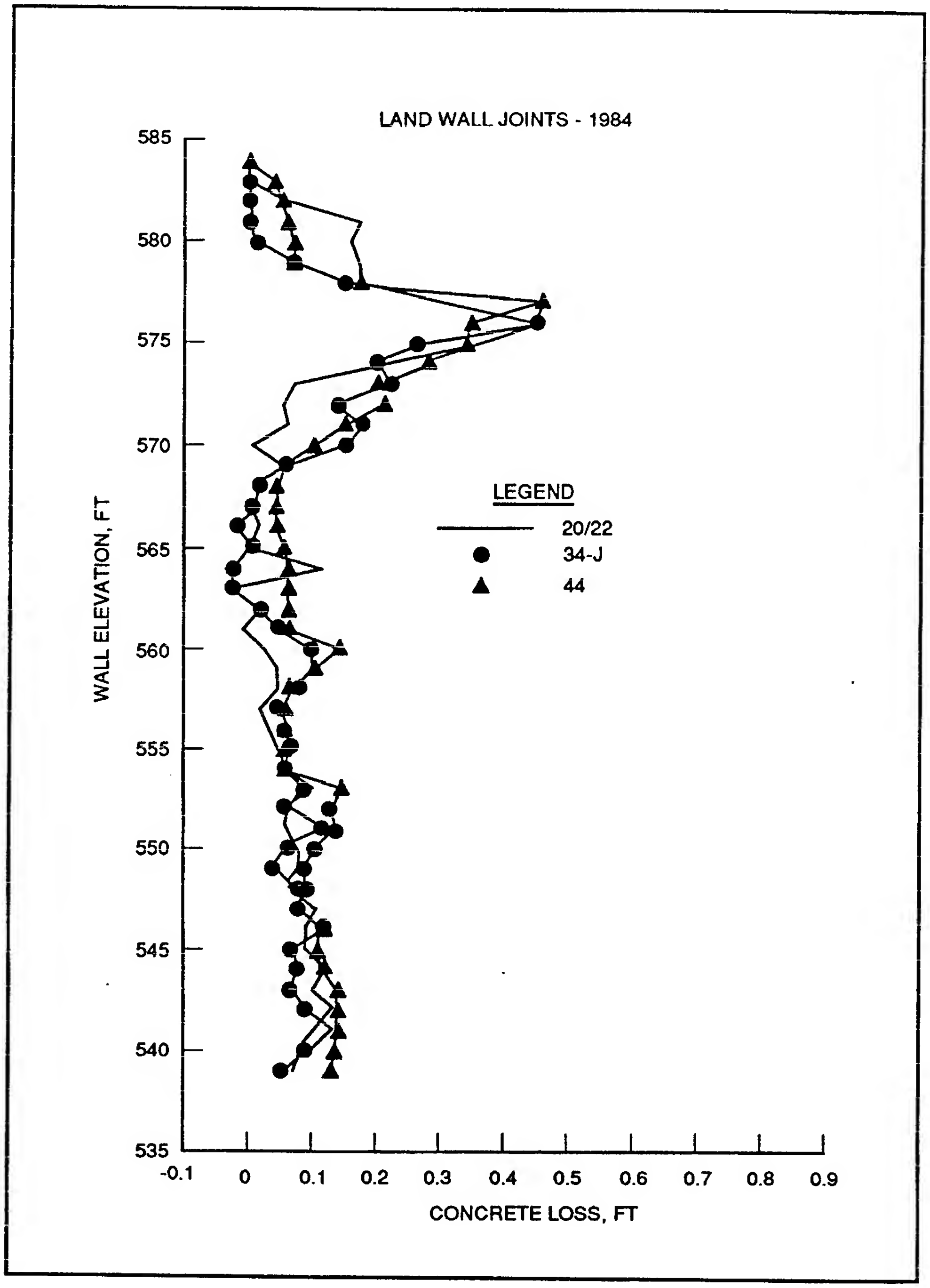

Figure 4. Loss measurements for Lockport land wall joints, 1984

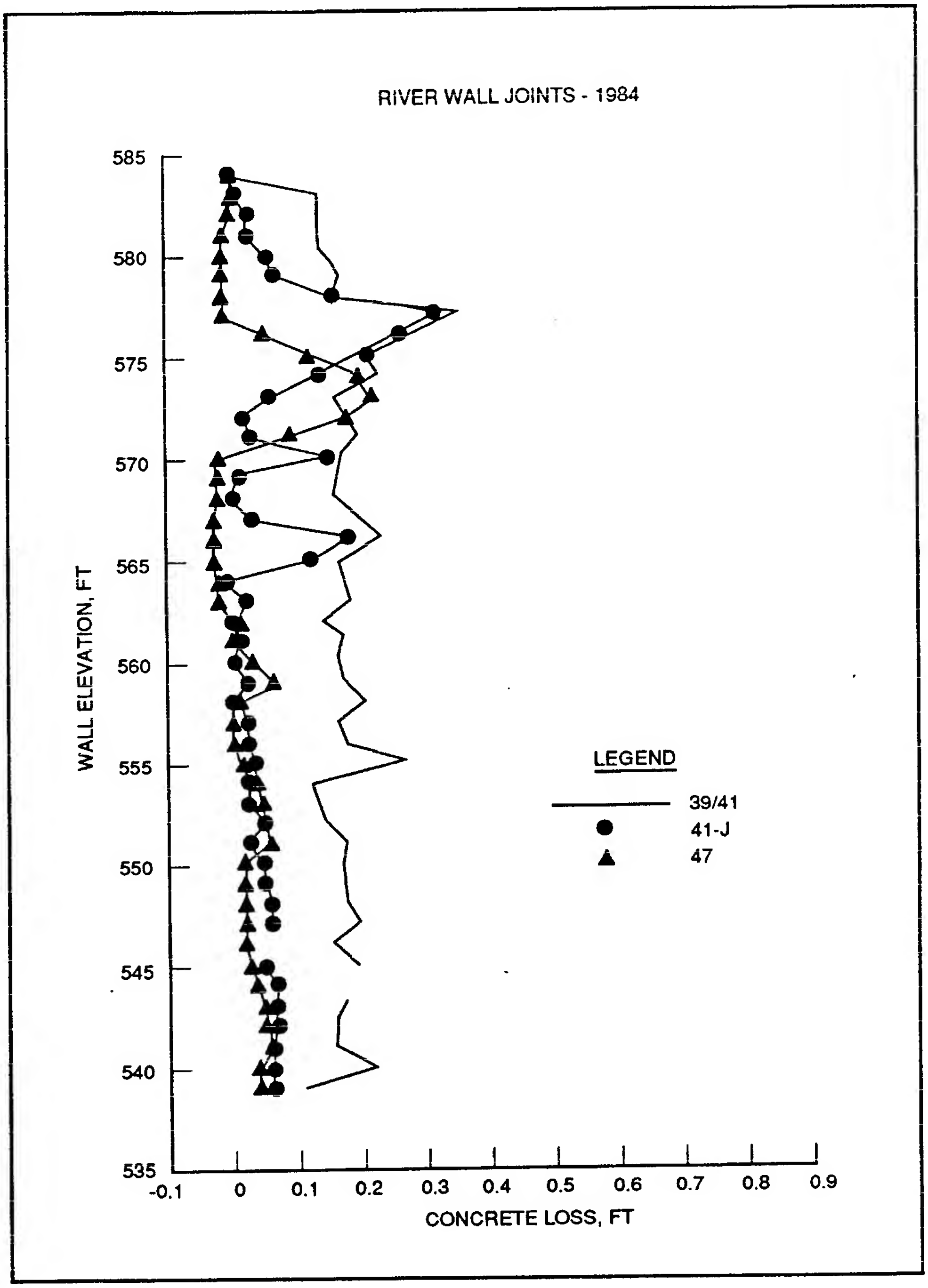

Figure 5. Loss measurements for Lockport river wall joints, 1984

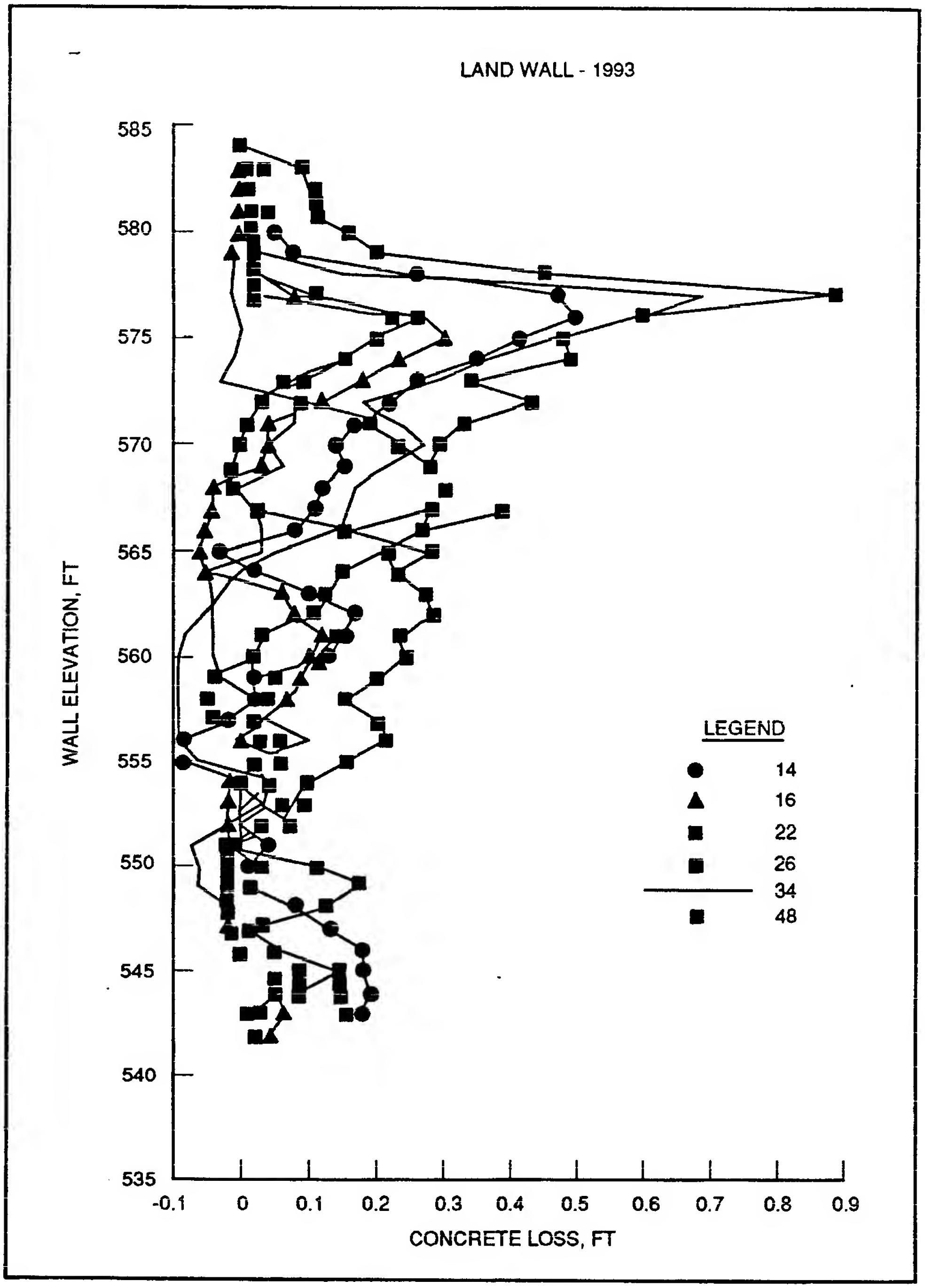

Figure 6. Loss measurements for Lockport land wall monoliths, 1993

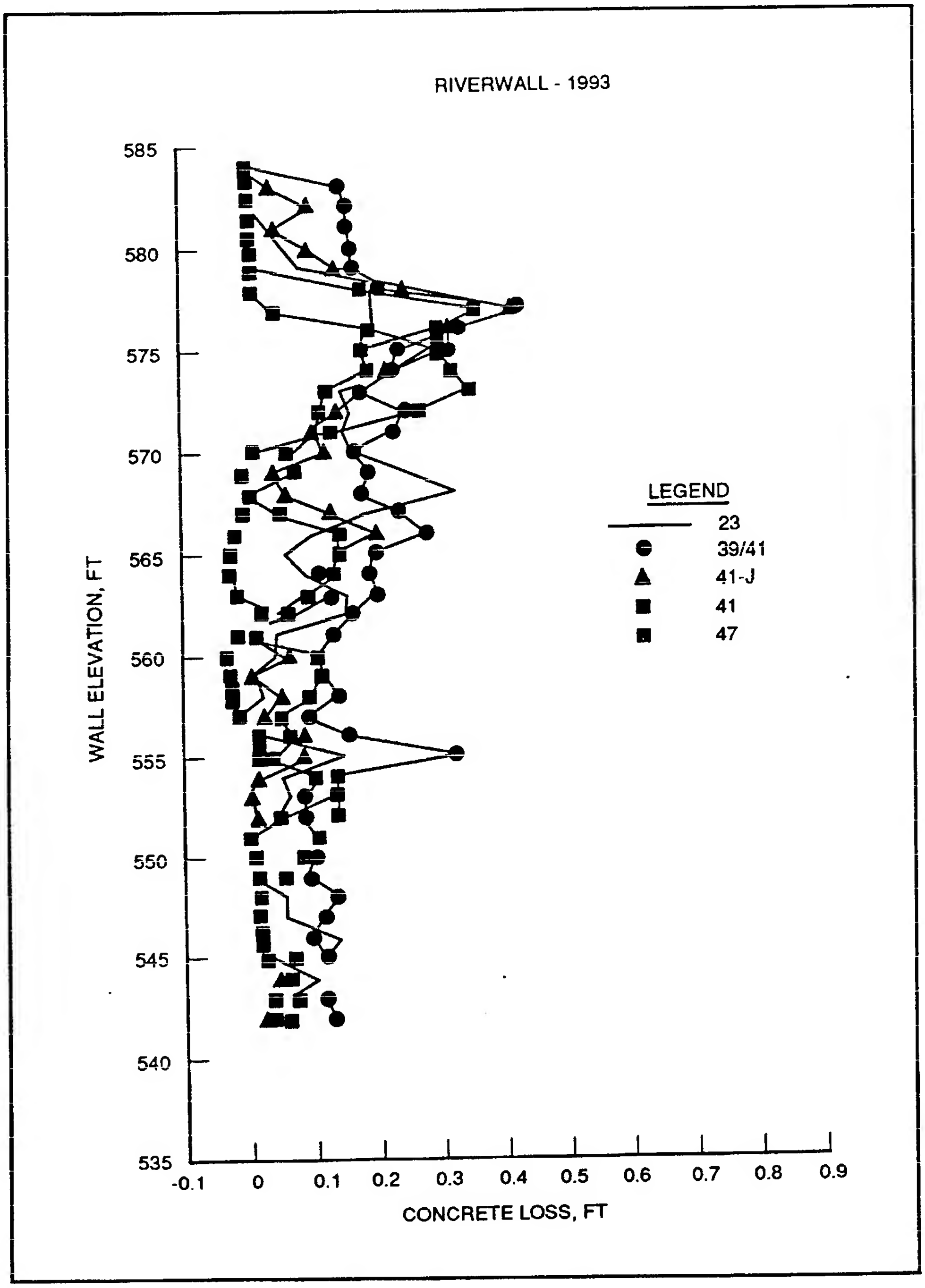

Figure 7. Loss measurements for Lockport river wall monoliths, 1993

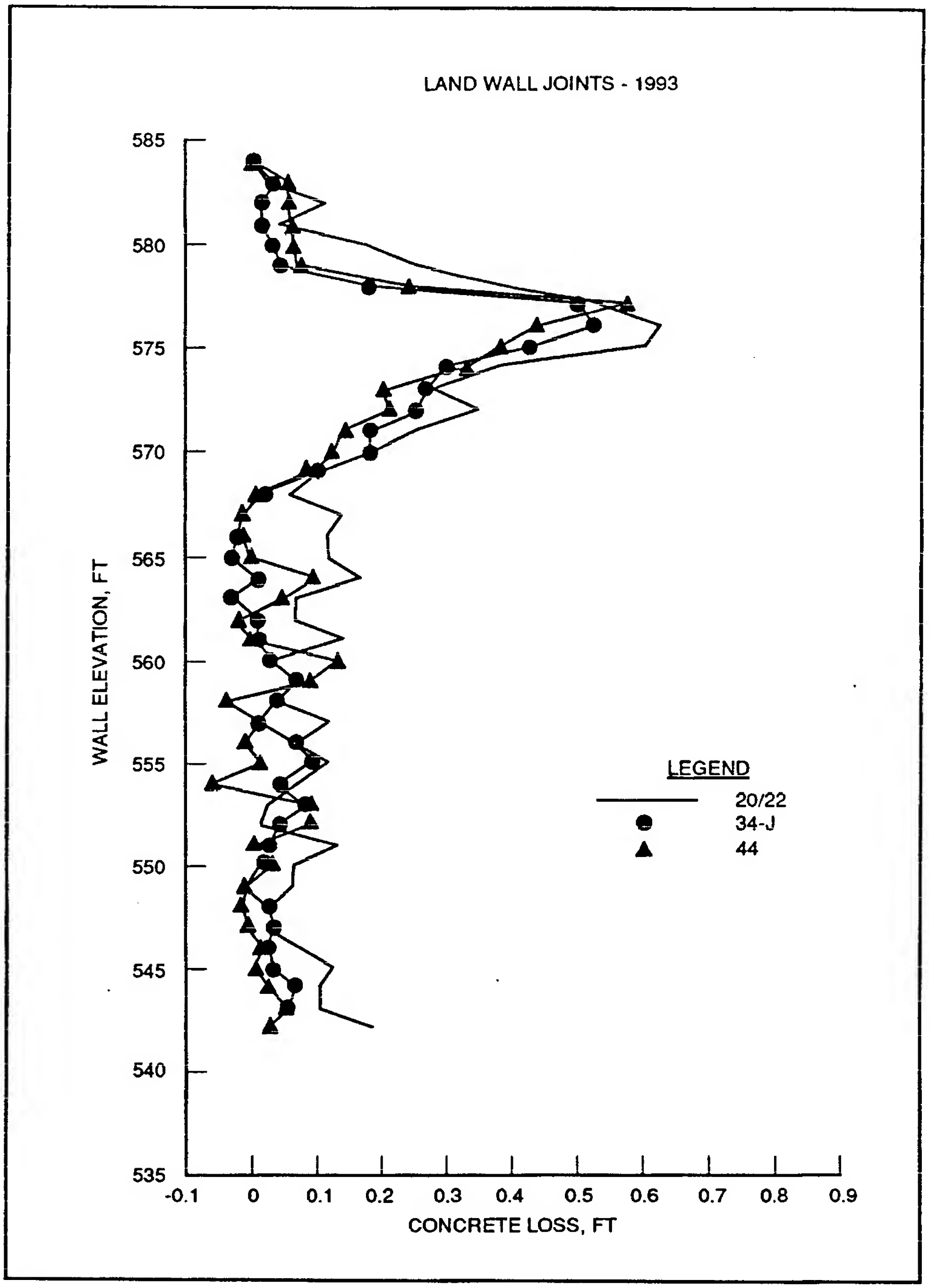

Figure 8. Loss measurements for Lockport land wall joints, 1993

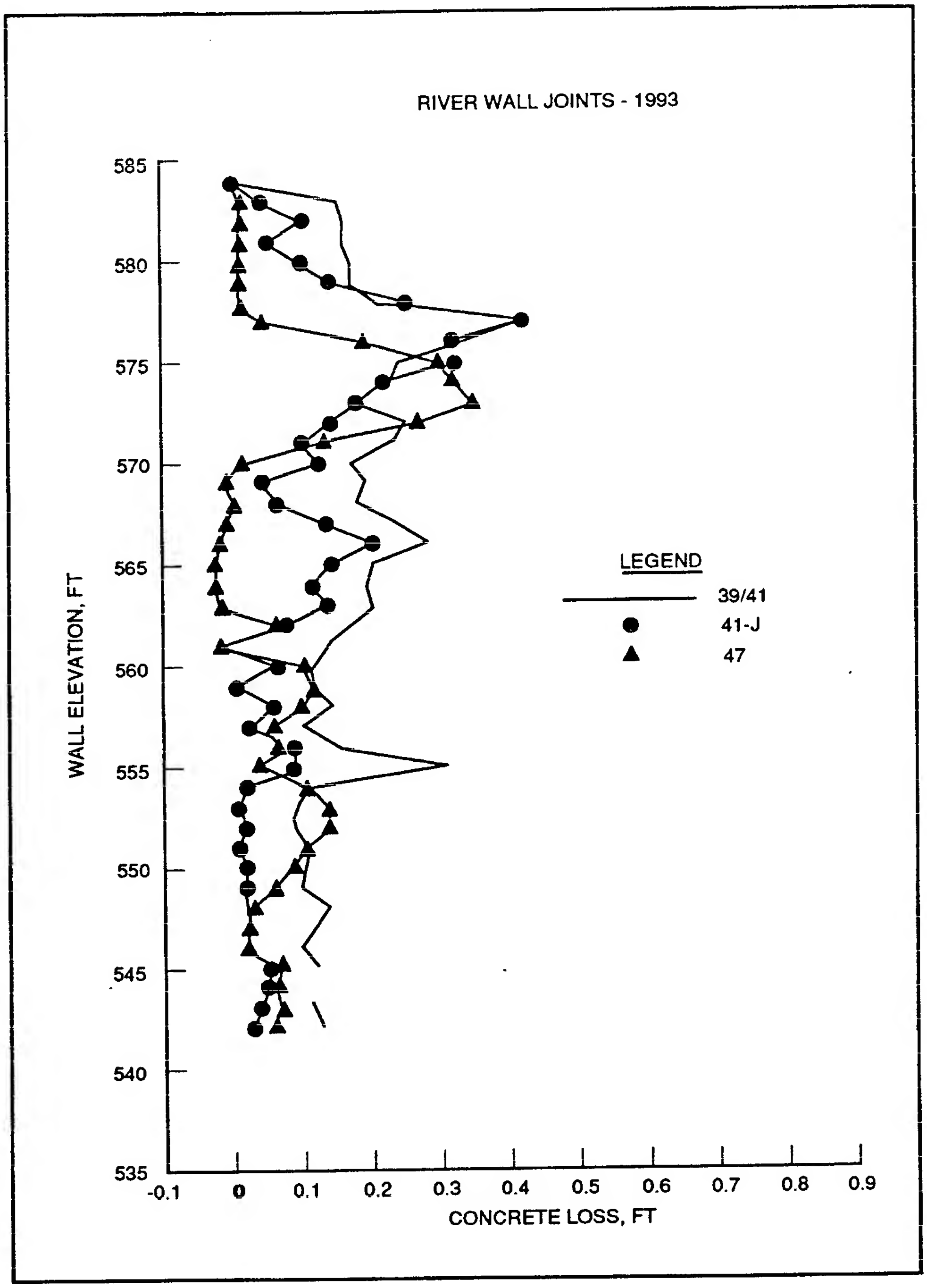

Figure 9. Loss measurements for Lockport river wall joints, 1993

Point Marion Lock and Dam - Monongahela River

Point Marion Lock and Dam was constructed in the 1930's and, like Lockport, has suffered measurable concrete loss from the lock wall vertical surfaces. In fact, a shotcrete rehabilitation of the chamber was conducted in the late 1950's. Measurements made in September 1993 confirmed that much of the 3-in.-thick shotcrete layer had debonded and fallen off the vertical walls. The measurements were made at 1-ft el increments at several locations along individual selected monoliths on both the land and river walls. Losses along the selected monoliths range up to about 12 in., with land wall losses generally higher than those on the river wall. These losses are attributable to the preference of mooring the tows on the land side of the chamber. The losses are generally higher in the upper regions of the walls near upper pool el 793.

The data from these measurements are presented for various monoliths in Figures 10 through 14. Specifically, measurements are depicted for different positions along land wall monoliths 15, 19, and 21 and river wall monoliths 5 and 11 in these figures.

Lock and Dam 13 - Mississippi River

Lock and Dam 13 (Figure 15) was operational in 1939. The lock chamber has suffered sporadic loss of concrete from the lock wall surfaces. Measurements of the lock chamber taken in October 1994 indicated that a majority of the vertical surfaces were in excellent condition except at monolith and construction joints and around the gates. These patterns of deterioration are generally exhibited at most locks because these areas are subjected to an increased number of barge impacts. Lock 13 underwent complete vertical wall replacement during the winter months of 1994.

Measurements were taken at a total of five monoliths on both the intermediate and landside walls. The maximum losses ranged from 1 to 1.5 in. and were concentrated near lower pool. This loss can be attributable to abrasion from a concentration of barge impacts distributed over the lower pool level during most of the year. The lock is not typically subjected to any freeze-thaw except at the lower pool elevations since the lock is not in service from late December to early March, and the lock chamber is left at lower pool elevation. Lock 13 also does not flush ice during winter months because of the submersible gates on the dams which allow ice to flow over the dam.

Lock and Dam 15 - Mississippi River

Lock and Dam 15 (Figure 16), operational since 1934, was selected because it is one of the few locks that exhibits little or no loss of the vertical surfaces. Loss measurements were taken during October 1994 on a total of five land and intermediate monolith walls. All of the vertical surfaces appeared solid and in excellent shape, which may be attributable to admixtures in the concrete during construction. Any substantial losses which

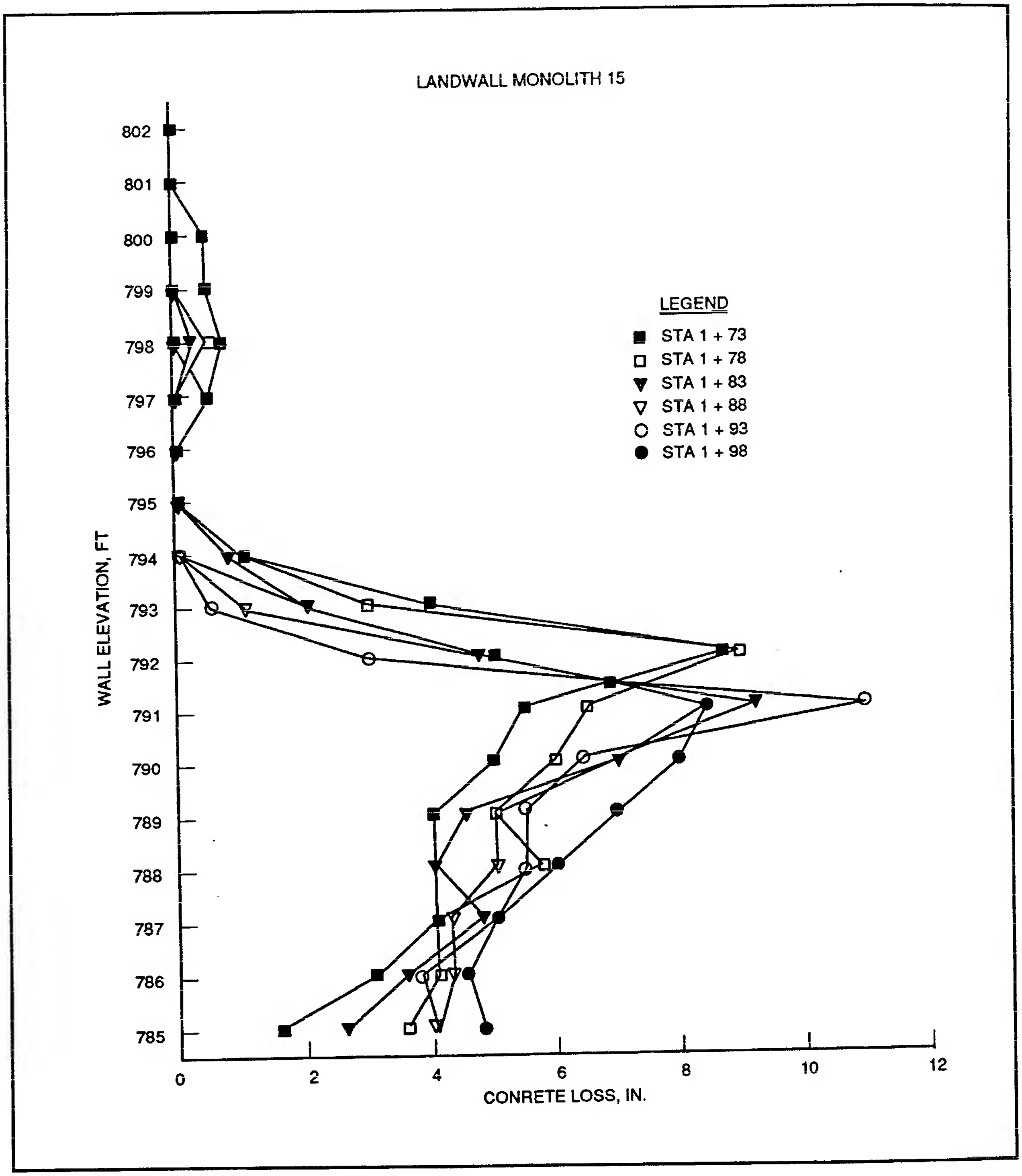

Figure 10. Loss measurements for Point Marion Lock and Dam land wall - Monolith 15

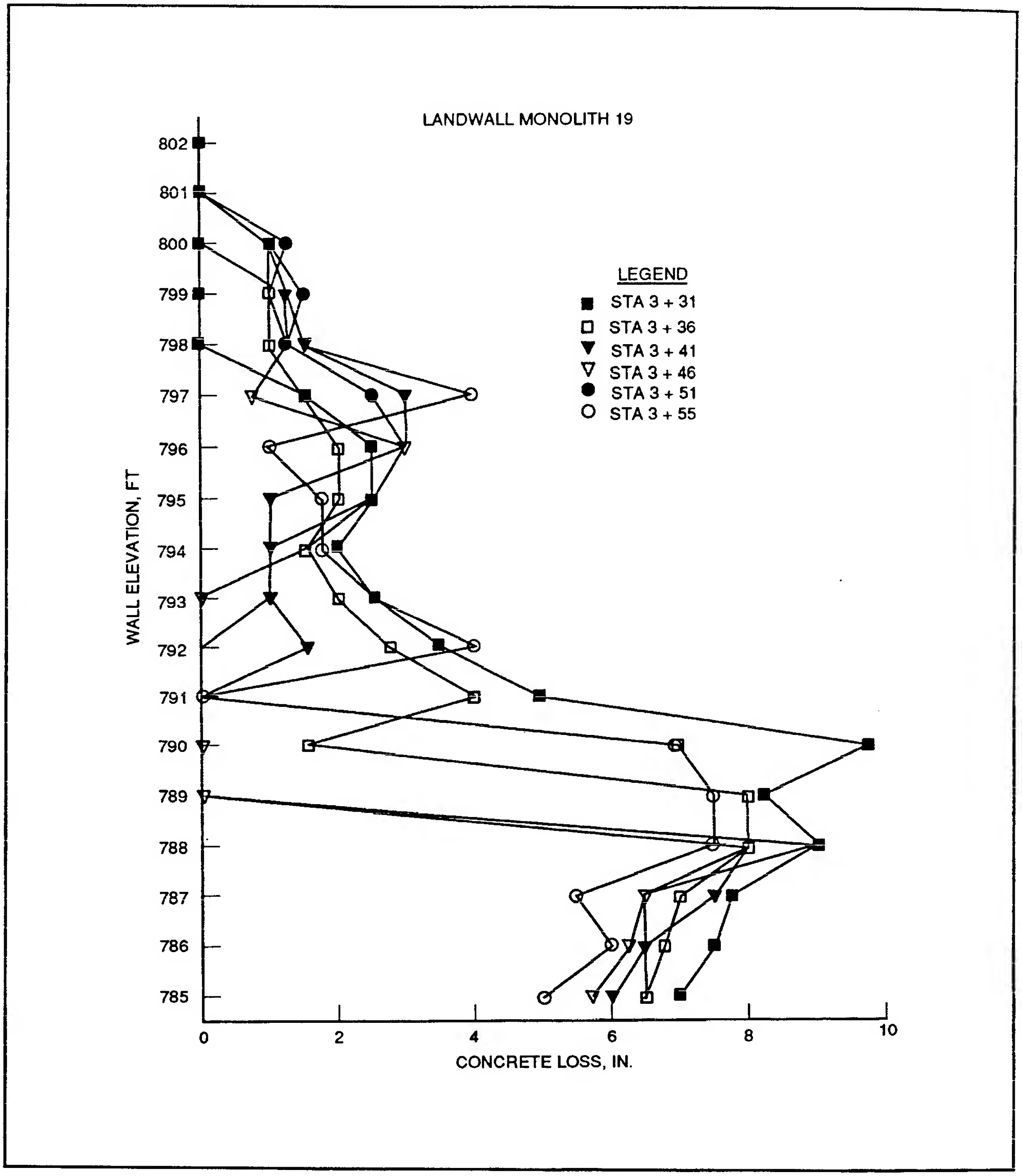

Figure 11. Loss measurements for Point Marion Lock and Dam land wall - Monolith 19

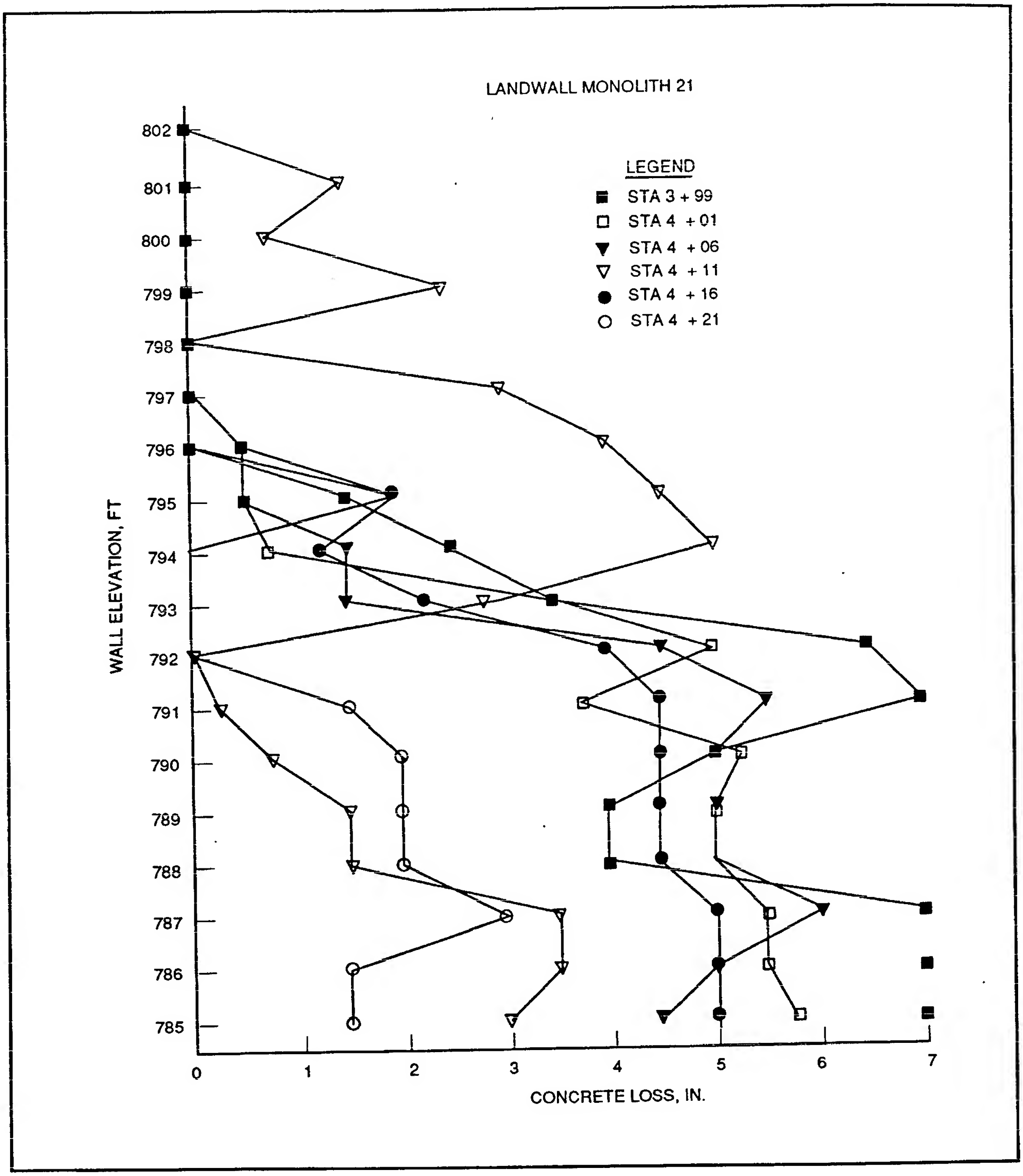

Figure 12. Loss measurements for Point Marion Lock and Dam land wall - Monolith 21

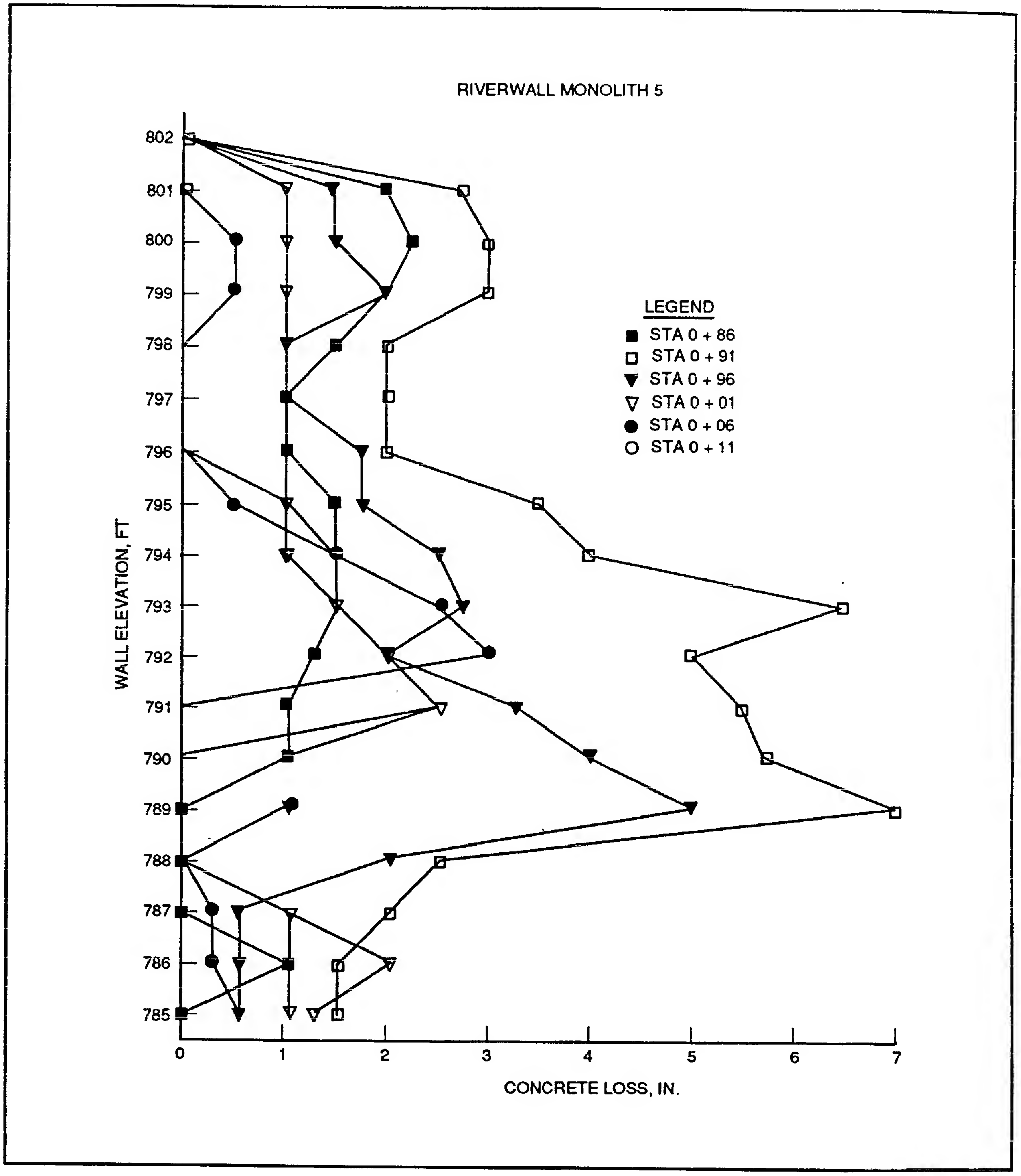

Figure 13. Loss measurements for Point Marion Lock and Dam river wall - Monolith 5

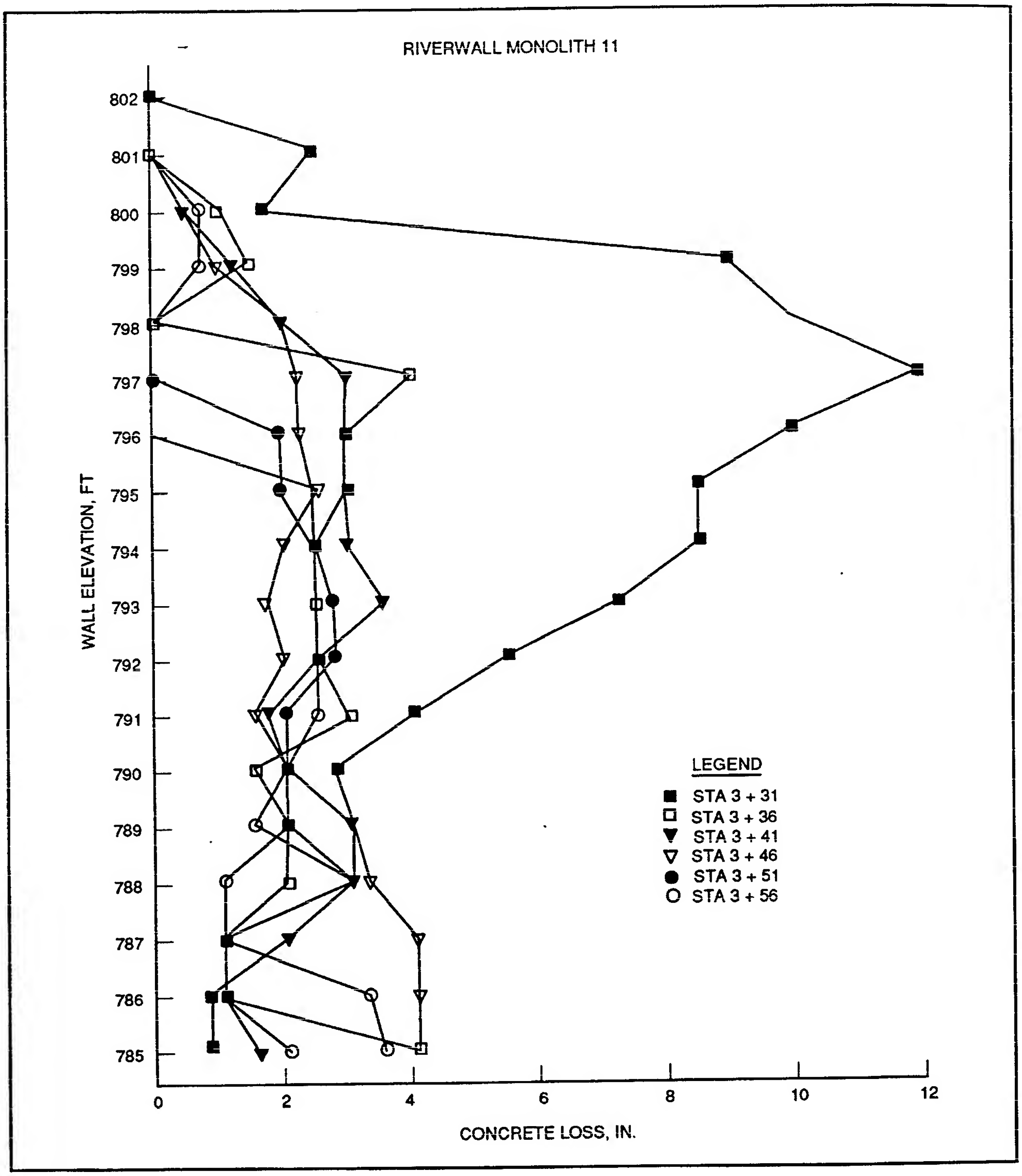

Figure 14. Loss measurements for Point Marion Lock and Dam river wall - Monolith 11

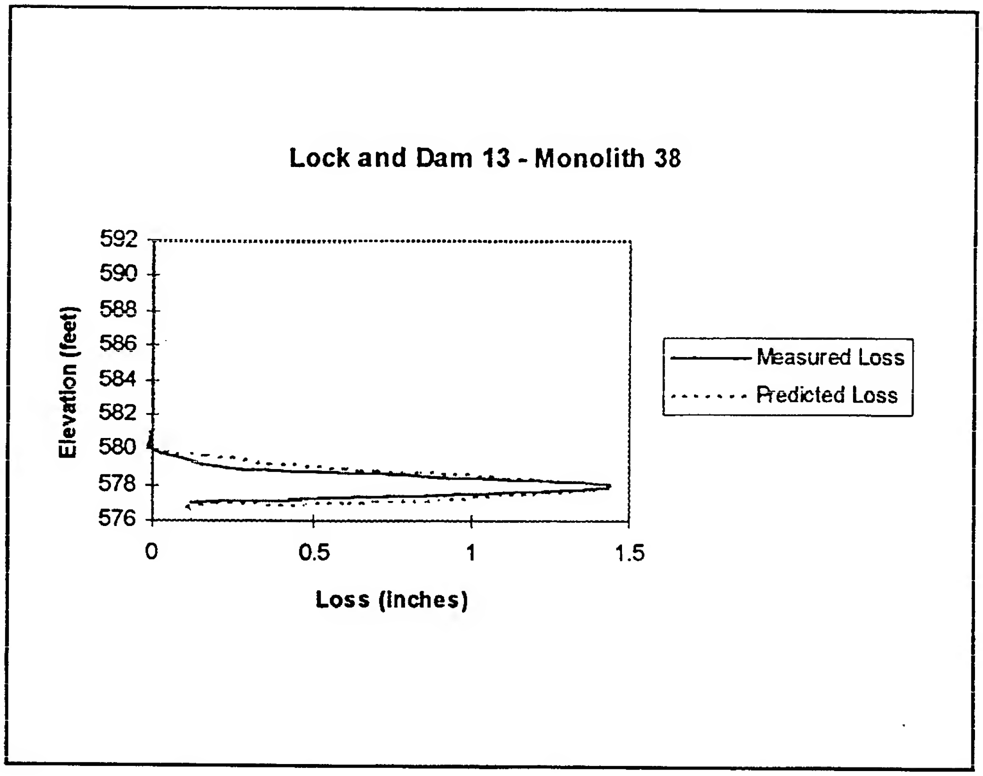

Figure 15. Loss measurements for Lock and Dam 13 - Monolith 38

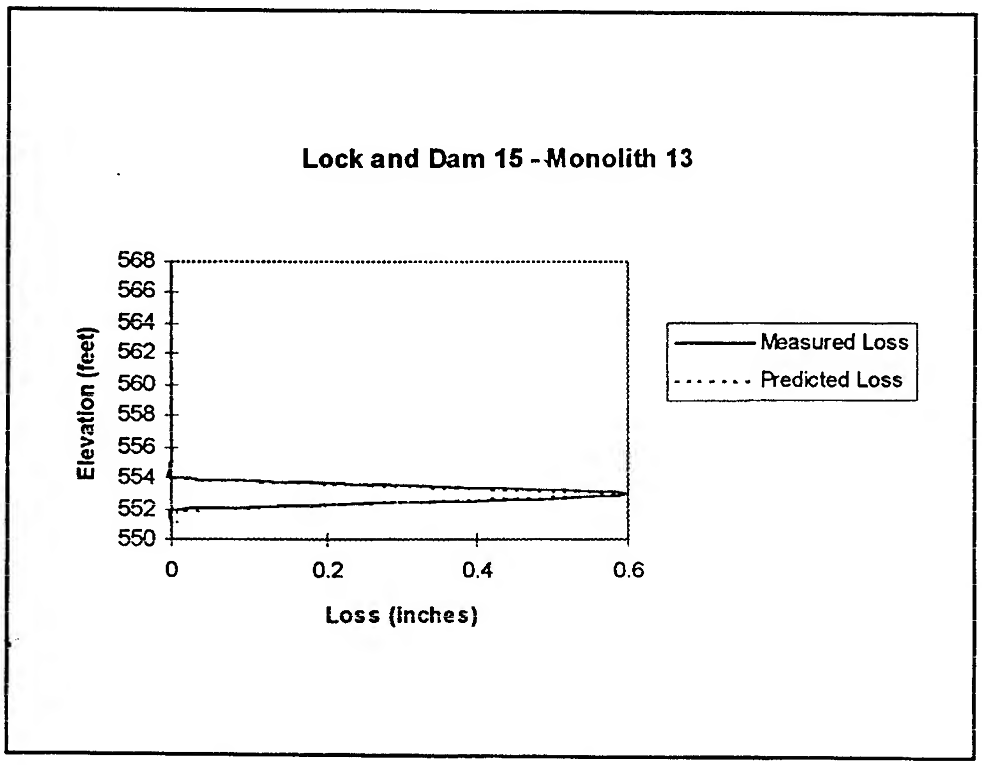

Figure 16. Loss measurements for Lock and Dam 15 - Monolith 13

were concentrated around the gates and construction joints were rehabilitated during the winter of 1993.

The losses were measured for the monoliths considered to be in the worst shape. Losses ranged from of 0.3 to 0.7 in. Similar to Lock 13, the losses were distributed around a zone at lower pool. This can also be attributed to the fact that the winter operation allows for the shutdown of the lock to river traffic and the chamber pool is left at lower pool level.

Data Tendencies and Observations

The first look at the data presented in the previous paragraphs leads to several general conclusions regarding any underlying tendencies of concrete loss. First, the observed loss for these lock walls does not follow the parabolic shape assumed in the prior study. The current data indicate more localized regions of high loss, generally not centered near midpool. In fact, where any observable pattern of deterioration exists in a set of measurements, maximum losses tend to occur near upper pool elevation with lesser losses at other elevations. There appears to be a general tendency for maximum loss near upper pool, another smaller maxima near lower pool, with lesser losses between pool levels decreasing to little or none near the wall top and bottom.

These observations of the patterns of deterioration not only follow from the data but satisfy plausible explanations of physical phenomena that may lead to the loss. Specifically, the loss of concrete is attributed to the combined effects of freeze-thaw deterioration and abrasion from transiting tows. From the abrasion side of this equation, it is obvious that more abrasion should be expected near the two pool elevations since these are the levels at which tows enter and exit the lock. Although rubbing of the walls by the tow is evident during chamber filling and emptying, the resulting forces and abrasion damage should be significantly less in this region due to the much smaller barge velocities involved.

Previous studies have shown that freeze-thaw effects and deterioration should be expected to be higher near upper pool, compared to other elevations. Above this elevation, the degree of saturation in the concrete is generally less than the critical value required for freeze-thaw damage since external water levels remain below this elevation. Below upper pool where saturation may be critical, the insulating effects of water in the chamber tend to keep concrete temperature above the critical temperature for damage. Thus, the concrete in the upper pool region has a higher probability of freeze-thaw damage. Freeze-thaw damage generally decreases with decreasing elevation below upper pool. In addition, since the upper pool elevation is maintained relatively constant and the lower pool (tailwater) varies considerably, barge impacts are concentrated over a smaller height near upper pool, leading to higher concrete loss.

The combination of higher abrasion near pool levels and higher probability of freeze-thaw damage near upper pool supports a rationale for the observed loss at Lockport and Monongahela 8. There is also a likelihood

that losses should be higher between pool levels than above or below these elevations. The data and physical phenomena indicate a loss pattern that increases from some point below the wall top to a maximum near upper pool, decreases for some distance, and generally is less to near midpool. The pattern appears somewhat reflected below midpool but with lesser magnitudes of loss. This general pattern provides the basis for selection of analytical functions to represent concrete loss for the model.

One final observation regarding the data and the mechanics of the vertical surfaces model permits a simplification in the analysis of the data for a representative loss function. The data and physical phenomena indicate that losses are generally higher in the upper regions of the lock wall, particularly near upper pool. Since tows necessarily transverse the full height of the wall between upper and lower pool, and the operational problem is more critical where slopes (losses) are larger, it is really only necessary to consider the vertical surface in the upper region.

Analytical Representation of Loss

The foregoing observations of measured concrete loss at Lockport and Monongahela 8, along with the application of rational notions of the causes of such loss in general, led to some general characteristics of an analytical function that would be representative of these and other structures in this region. These characteristics are summarized as:

a. Higher loss near upper pool.

b. Some lesser losses between upper pool and midpool.

c. Loss near lower pool.

Several analytical functions that could satisfy these general characteristics were evaluated for appropriateness by two measures. First, they should provide a reasonable "fit" to the measured data, as reflected in a linear regression. The criteria are relatively obvious considering the intended purpose of prediction. Second, the functions should be simple enough and require minimal input to describe the vertical surface. The criteria follow from the need for a relatively simple method to predict wall slope given a limited amount of information regarding concrete loss. A number of functions, and combinations of functions, including polynomial expansions, fit to the data with limited success are not presented herein. The functional form that best met the above criteria is discussed in the following text.

A functional form that satisfied the loss characteristics listed previously and met the evaluation criteria quite well was a linear combination of three distinct functions that individually match with the listed characteristics.

This function for loss $Z(y)$ is

$$Z(y) = \sum C_i Y_i(y) \tag{6}$$

where

$$Y_0 = \text{constant} \qquad y \le y_{pml} - w_2 \tag{6a}$$

$$\begin{aligned} Y_1 &= \cos^2(\pi(y - y_{pml})/2w_1) && y_{pml} \le y \le y_{pml} + w_1 \\ &= 0 && \text{elsewhere} \end{aligned} \tag{6b}$$

$$\begin{aligned} Y_2 &= \cos^2(\pi(y - y_{pml})/2w_2) && y_{pml} - w_2 \le y \le y_{pml} \\ &= 0 && \text{elsewhere} \end{aligned} \tag{6c}$$

and

y_{pml} = elevation at upper pool
w_1 = range of $\cos^2()$ function above upper pool
w_2 = range of $\cos^2()$ function below upper pool

and is depicted schematically in Figure 17. The constant term, Y_0, provides the consistent losses below upper pool that may be due to causes other than typical abrasion and freeze-thaw, e.g., during pool filling and emptying. The second term provides for a region of higher losses above upper pool over a range of "w_1" feet (and zero outside this range) that is maximum at upper pool and is continuous in the first derivative. The

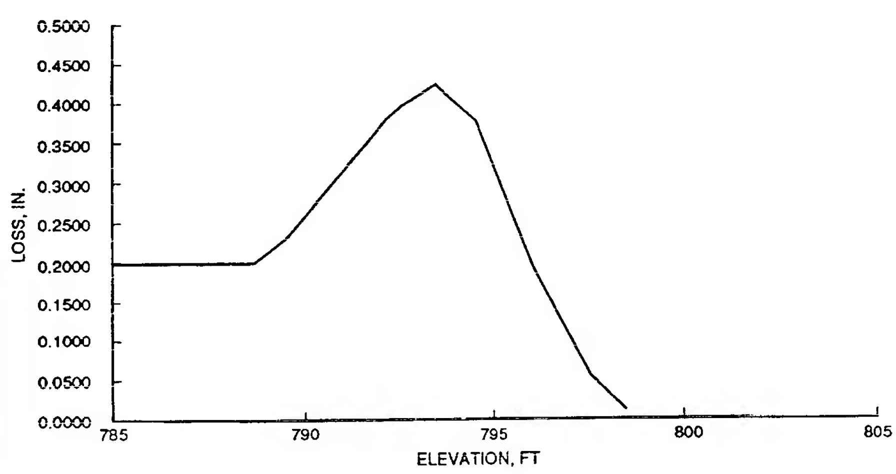

Figure 17. Functional form selected for model (Equation 6)

third term provides for a region of higher losses below upper pool over a range of "w_2" feet (and zero outside this range) that is maximum at upper pool, decreases to the constant value Y_0 at $y_{pml} - w_2$, and is continuous in the first derivative. The second and third terms are associated with the direct abrasion during tow entry and exit of the lock chamber.

Figures 18 through 20 show examples of the loss function (predicted) to the actual loss measurement taken in the chamber. The examples shown are an average representative of the fit of the function. Figure 18 is for Monolith 16 of Lockport Lock and Dam. The values used in the loss function $y_{pml} = 576$ (around upper pool), $w_1 = 2$, $w_2 = 9$, $Y_0 = 0.1$. Figure 19 is for Monolith 38 at Lock and Dam 13. The values used in the loss function were: $y_{pml} = 578$, $w_1 = 1.8$, $w_2 = 1.8$, $Y_0 = 0.27$. Figure 20 is for Monolith 13 at Lock and Dam 15. The values used for the loss function were: $y_{pml} = 553$, $w_1 = 0.95$, $w_2 = 1$, $Y_0 = 0.01$.

This functional form was evaluated for "goodness of fit" via linear regression where (1) $Y_i(y)$ are the independent variables, (2) $Z(y)$ is the linearly dependent variable, and (3) the coefficients C_i were determined using spreadsheet analysis. The linear regression was performed solely on loss data normalized by the maximum value, i.e., the loss function ranged from -1.0 to +1.0 (primarily positive). The linear regressions for selected sets of data from the measurements at Lockport are presented in Figures 21 through 23. The magnitudes of "w_1" in Equation 6b and "w_2" in Equation 6c were selected after a few trials using the available data. The values for w_1 and w_2 for Locks 13 and 15 are shown in Table 1.

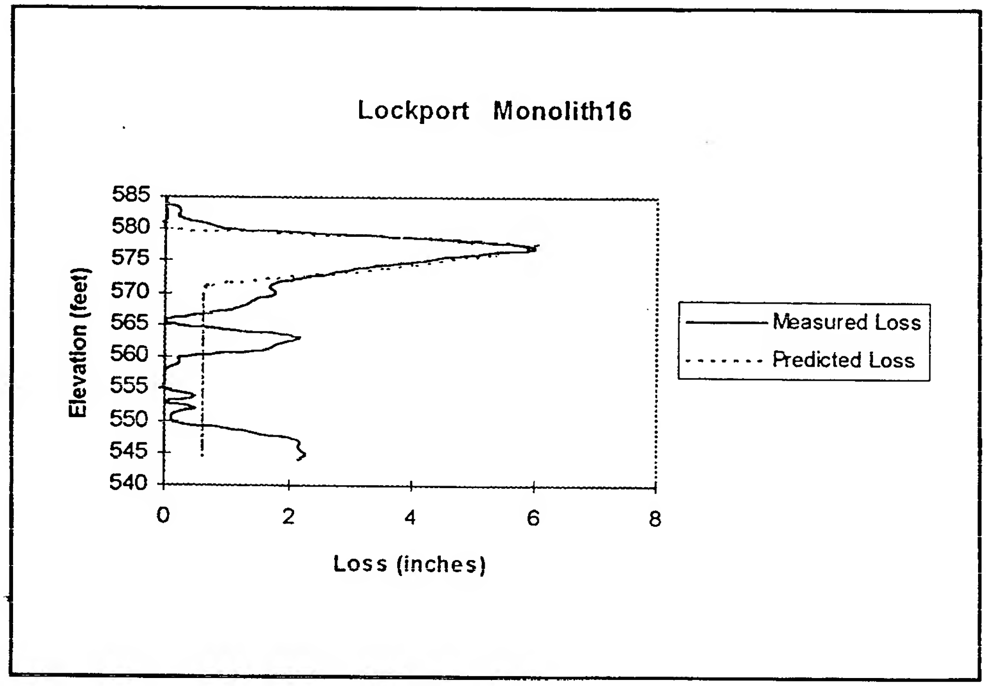

Figure 18. Measured versus predicted losses at Lockport Lock and Dam

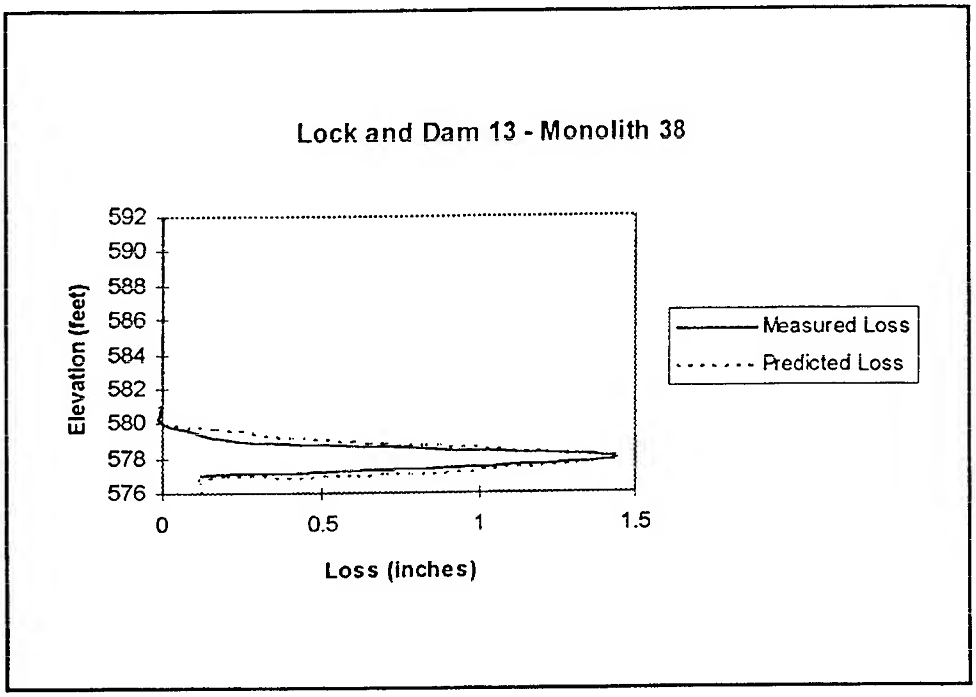

Figure 19. Measured versus predicted losses at Lock and Dam 13

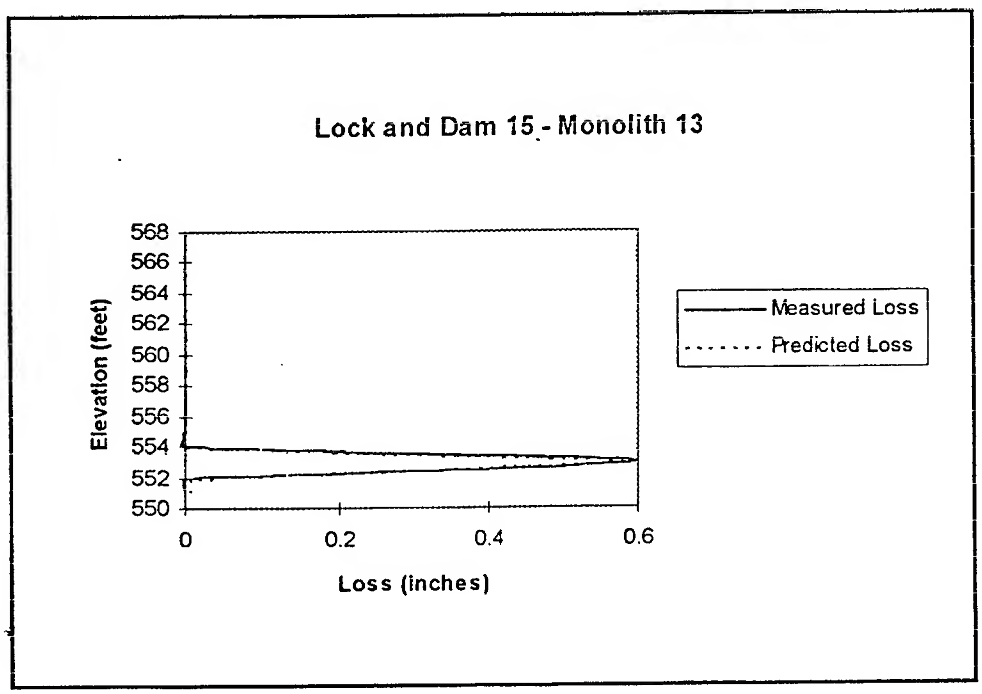

Figure 20. Measured versus predicted losses at Lock and Dam 15

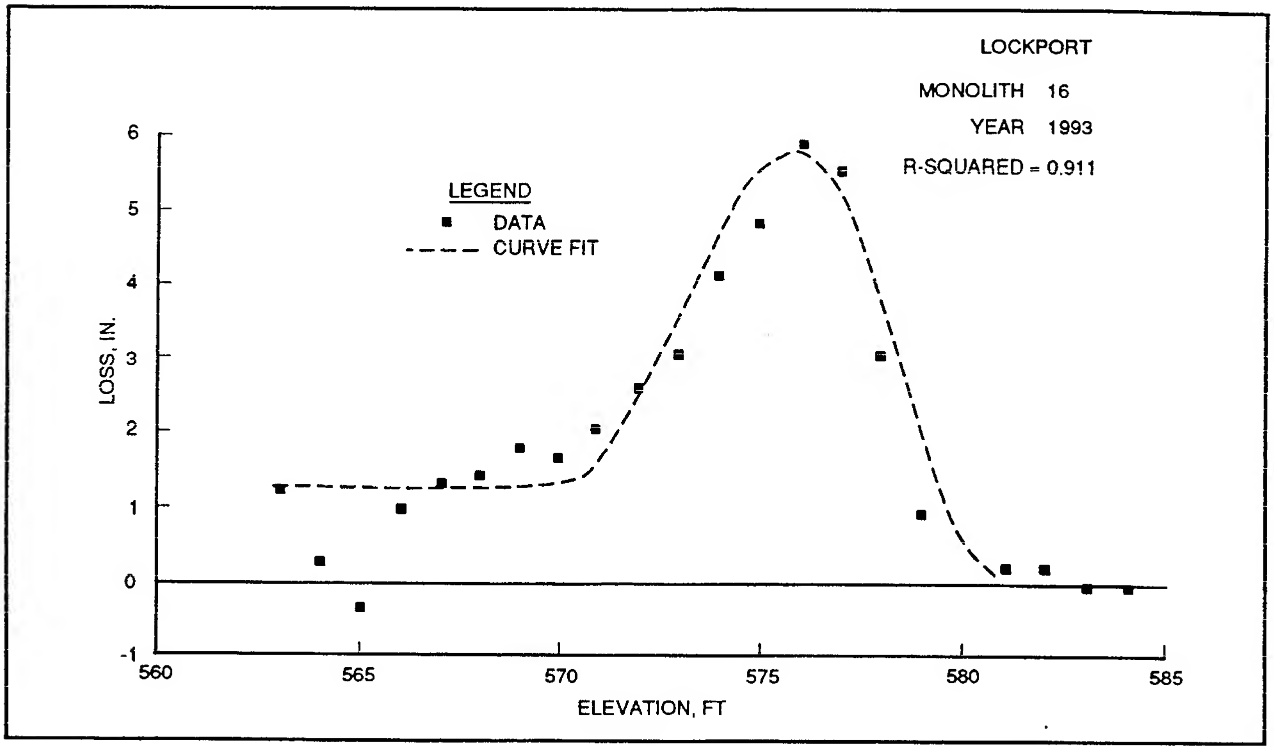

Figure 21. Linear regression for Lockport Monolith 16, 1993

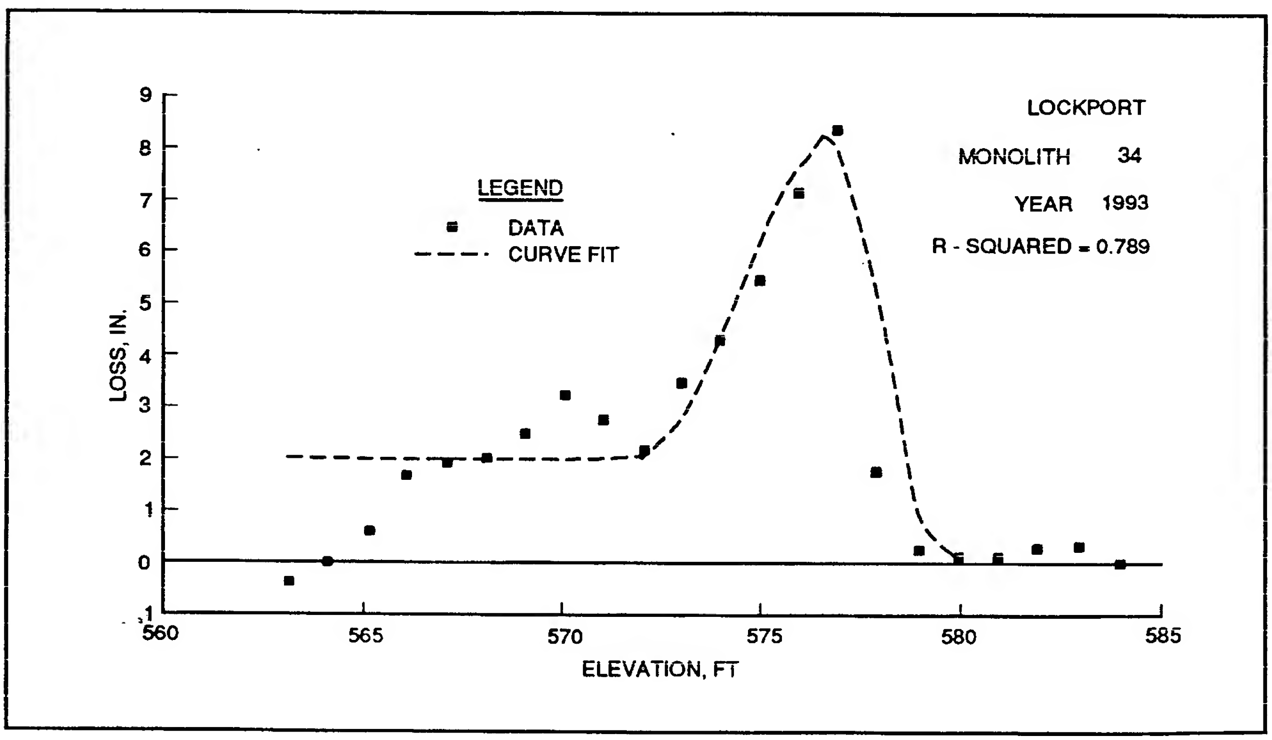

Figure 22. Linear regression for Lockport Monolith 34, 1993

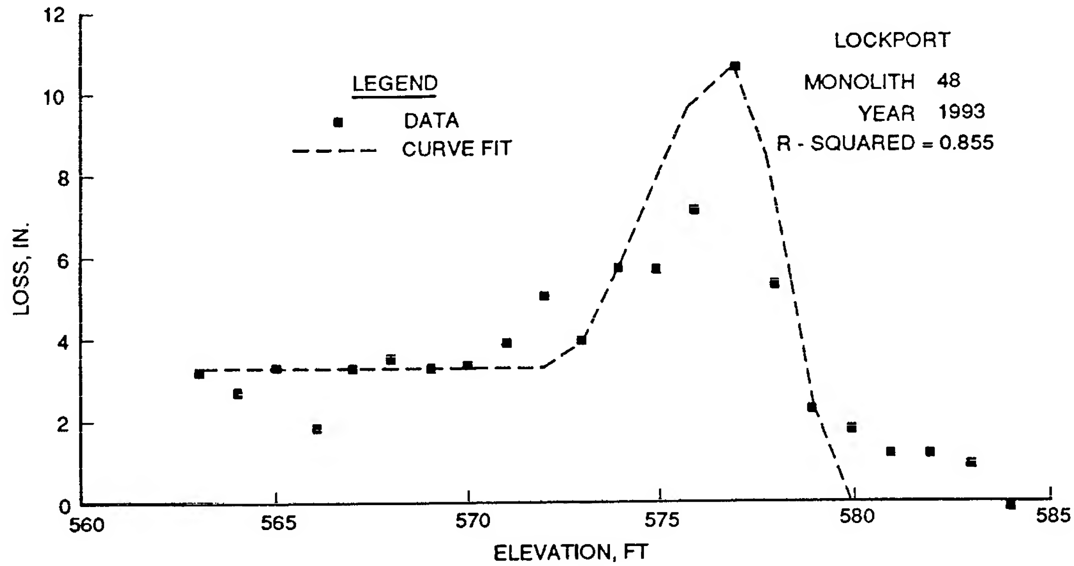

Figure 23. Linear regression for Lockport Monolith joint 48, 1993

Table 1
Measured Lock Parameters for Upper Mississippi Lock Chambers

Lock-Monolith	w_1, ft	w_2,ft	r	Measured Loss, in.	Evaluation of Maximum Loss, ft
Lock 13 - Upper Pool 583 Lower Pool 572					
13-41	2.5	1.8	0.27	0.84	581
13-42	1.47	3	0.1	0.6	587
13-38	1.45	1.5	0.1	1.43	578
13-25	1.73	1.5	0.1	0.83	580
13-16	3.4	2.8	0.05	0.6	579
Lock 15 - Upper Pool 561 Lower Pool 545					
15-25 (a)	1.2	2.2	0	0.141	566.9
15-25 (b)	1.2	2.2	0	0.141	551.9
15-15	1.2	0.89	0	0.89	552
15-13	1.2	0.89	0	0.63	553
15-8	1.2	1.455	0	0.243	554
15-16	1.2	1	0	1.117	558

The data and linear regression for Lockport Monolith 16, 1993 measurements, are presented in Figure 21, for the region between top of wall (el 585) and midpool elevation (el 563). The data and the "best fit" curve for the function are plotted. The individual points are the measurements and the dashed line is the curve fit. The goodness of fit is measured quantitatively by the R^2 term, i.e., the closer R^2 is to unity, the "better" the fit. The R^2 value for this case of 0.91 represents a good fit to the data using this functional form. This quantitative assessment is reinforced by the graphical comparison of the data and the regression line.

A similar result for the data from Monolith 34 in 1993 is presented in Figure 22. In this case the regression is reasonably good ($R^2 = 0.79$). The curve fit captures the essential features of the concrete loss required to determine the governing slope for the lock wall limit state previously described. The data and curve fit for Monolith 48 (1993) are shown in Figure 23. Again, the regression is good ($R^2 = 0.86$), and the curve fit captures the essential features of the concrete loss.

Relative Concrete Loss at Midpool and Upper Pool

The vertical surfaces model requires, in addition to definition of specific elevations and loss widths (w_1 and w_2), the prediction of loss at upper pool and nearer midpool (constant function). The prediction of maximum concrete loss due to freeze-thaw degradation and barge impact abrasion at upper pool is described by Patev et al.[1] A similar analytical model is not available for predicting the lesser losses near midpool, particularly since the transiting barge impact parameters are not significant nor easily defined. Due to this lack of an analytical procedure for predicting this lesser loss magnitude, the existing loss data were examined to determine any relationship between upper pool loss and midpool loss. Specifically, the ratio of average midpool loss to upper pool loss was determined for each set of measurements at Lockport Lock, Point Marion Lock and Dam, and Locks and Dams 13 and 15 (Table 1), i.e.,

$$r = \frac{\textit{average midpool loss}}{\textit{upper pool loss}}$$

This ratio is utilized to predict midpool loss in the vertical surfaces model. Specifically, the upper pool loss is determined from the concrete loss model described by Patev et al.,[1] and the midpool loss is computed directly using the above ratio.

[1] R. C. Patev, Reed L. Mosher, Mary Ann Leggett, Paul F. Mlakar, and Larry M. Bryant. "Reliability analysis of lock walls subjected to concrete deterioration due to freeze-thaw and abrasion" (Technical report in preparation), U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Refined Model

The vertical surfaces model for the limit state of the barge "hanging up" on uneven slopes of the lock wall is based on the refined prediction of the loss function along the wall. This refined model is depicted schematically in Figure 24. The basics of the friction model are the same as the previous model, with the slope of the wall being determined from the refined prediction of concrete loss along the wall described in the previous section.

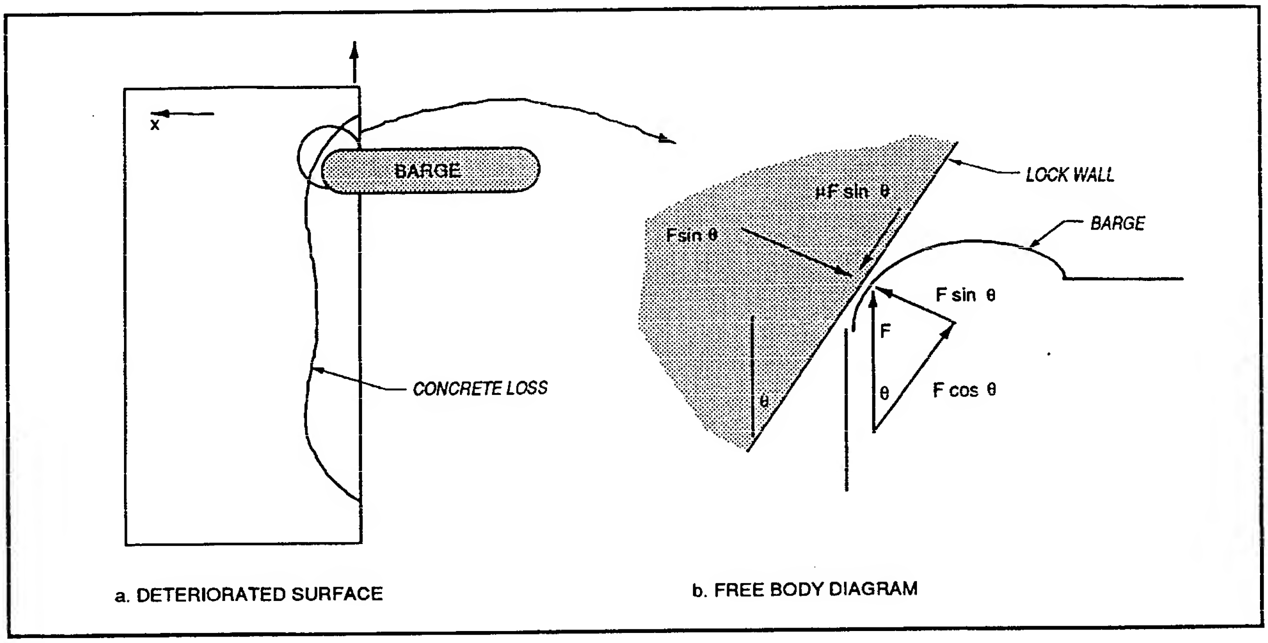

Figure 24. Refined vertical surfaces model

In the previous model, there was no question as to the location of the maximum slope of the wall that could impinge barge motion. In that case, the maximum slope was at the top of the deteriorated surface and could be calculated directly. In the refined model it is more difficult to determine the location and magnitude of the maximum *admissible* slope, i.e., where a barge could actually encounter the wall. Specifically, the point of contact along the surface above upper pool may be limited by the minimum loss value below upper pool if the barge draft is large compared to the combined widths of the upper pool loss ($w_1 + w_2$). If the combined widths of loss are large compared to the barge draft, the barge could translate and move between the slopes below and above upper pool, leading to a different contact point and different slope.

Thus, the maximum admissible slope must be determined from both the concrete loss function and the barge minimum draft. The calculation for maximum admissible slope in the current model numerically considers 10 evenly spaced potential points of contact in the region of highest slope. If any point is admissible from considerations of geometry, the slope is then likewise admissible. The largest of these admissible slopes is then used in the limit state.

3 Data Collection Using Time-Lapse Videotape

Introduction

Reliability assessment models focus on limit states which inherently use random variables. Proper estimates of these variables are crucial to the successful development and implementation of reliability models. The collection of physical data for reliability purposes is often a very expensive and tedious work effort. However, use of time-lapse videotape monitoring is an inexpensive, accurate, and economical way to obtain and permanently catalog field data.

The collection of physical data from lock chambers was required to properly develop the models for concrete deterioration and loading cycles for the fatigue assessment of hydraulic steel structures used for the U.S. Army Corps of Engineers (USACE) UMR-IWW Navigation Study. The UMR-IWW Navigation Study is currently being used to prioritize navigation investment decisions to the year 2050 for the 37 locks and dams in the UMR-IWW navigation area using reliability-based assessment methods.

The objectives of the work were to investigate and document unknown or estimated variables for reliability assessment models. Statistical data needed for these models were collected from the time-lapse videotape monitoring of three lock chambers in the UMR-IWW navigation area. Each item was crucial in developing the proper constraints to be used in the reliability assessment models.

Since the field collection of physical data is often a time-consuming task, time-lapse monitoring was implemented to assist with physically cataloging over 12,000 hours of field data at a minimal cost. The collected data characterized the values for the number of impacts on lock walls that occur during a lockage, the velocity of a barge in three different locations in a lock chamber, the fluctuation of chamber pools with time, and the number of unrecorded lockages for ice. These data were used as a basis in the successful implementation of the reliability models, since the constraints of these models were based directly on input of variables or constants in the probabilistic models.

Time-Lapse Video Technology

The technology of time-lapse video has been applied to many different fields of engineering. The application to collection of physical data for reliability assessment models has just entered its infancy. This technology provides the ability to collect data when it would be difficult or impossible to be physically present. Many different extensions to the current technology are being developed by the USACE. Technological advances such as infrared cameras for night use, onscreen imaging of onsite data collection equipment, and solar power units enhance video technology.

The basic equipment required for time-lapse videotaping is rather simplistic. Only a time-lapse video recorder and camera are required. Video cameras can have either a wide angle or telephoto lenses. The cameras and recorders can be enclosed in weatherproof cases that are small enough to be mounted anywhere. Heaters and cooling fans can be installed in the cases to control temperature extremes. Solar power panels can also be utilized in remote locations that do not have a source of power. The USACE has mounted cameras in locations such as near the tops of electrical transmission towers to remote navigation locations that have no access via roads.

The time-lapse recorder can record times from 2 to 480 hr on a single VHS cassette. A recording time of 120 hr allows a single frame to be taken every 2 sec. The time-lapse rates recommended by USACE based on recording 15 hr a day are shown in Table 2 below. Costs for the equipment are minimal when compared to possible real-time field collection costs of manpower time onsite including associated living expenditures. On average, the time-lapse video equipment costs range from $3,000.00 to $10,000.00 per set of recorder, camera, and weatherproof cases. Generally, the only maintenance after proper setup is removal of videotapes at the end of taping period. Very little onsite maintenance has been required by the USACE in using time-lapse video equipment.

Table 2
Recommended Time-Lapse Video Rates

	Time-Lapse Rate, Hours	Duration, Days	Seconds Per Frame
Accessible sites	120	7	2
Remote sites	240	14	4

The monitoring of two lock chambers in the UMR-IWW navigation area was performed to assist with determining various variables for the concrete deterioration model. This monitoring refined previously unknown or estimated values for the number of impacts that occur during a lockage at upper pool, the velocities of a barge in different locations in a lock chamber, and the fluctuation of chamber pools with time. All of

these parameters are directly input as variables or constants in the probabilistic model that is discussed by Patev et al.[1]

Two individual time-lapse video cameras and recorders were used to record lockages at each site. This capability allowed the cameras to capture each lockage in both the upstream and downstream directions. The cameras were installed and mounted on light standards approximately 20 to 22 ft above the ground surface. This was to ensure that they were out of the way from any possible operational interference with tows. The video cameras were also extended a few feet over the edge of the lock wall to permit a full view of the entire lock chamber.

The time-lapse video recorder was set up to tape for a time period from 5:00 a.m. (0500 hr) to 8:00 p.m. (2000 hr), 7 days a week. The video recorder was also programmed to imprint continuously the date and time on the video output. This greatly assisted with the logging of each lockage and with determining the barge velocities based on actual time in the field.

The lock monitoring was performed on Lockport Lock and Dam on the Illinois Waterway (Chicago Sanitary and Ship Canal), and Lock and Dam 22 on the Mississippi River. Lockport Lock and Dam was monitored from the period starting on December 16, 1993, and ending on March 31, 1994. This time frame represented approximately 15 total weeks of lockages. Both video cameras were installed and operational for a period of 10 weeks even under the worst effects from the weather in the Chicago area. However, the downstream camera did fail after a power surge during a snow storm and was not functional for the last 5 weeks of taping.

Lockport Lock and Dam - Chicago Ship and Sanitary Canal

Lockport was selected because it is one of the few locks in the UMR-IWW navigation area that is fully operational during the winter months. The selection of Lockport provided a significant number of lockages that could be analyzed for the data required for this study.

The tapes from Lockport were analyzed for the following information:

a. Number of bumps at upper pool and around the upper gate.

b. Barge velocities at upper and lower gates and at the midpoint of the lock chamber.

c. Average time periods of pool fluctuations.

The general location of the camera setup for Lockport is shown in Figure 25.

[1] Ibid.

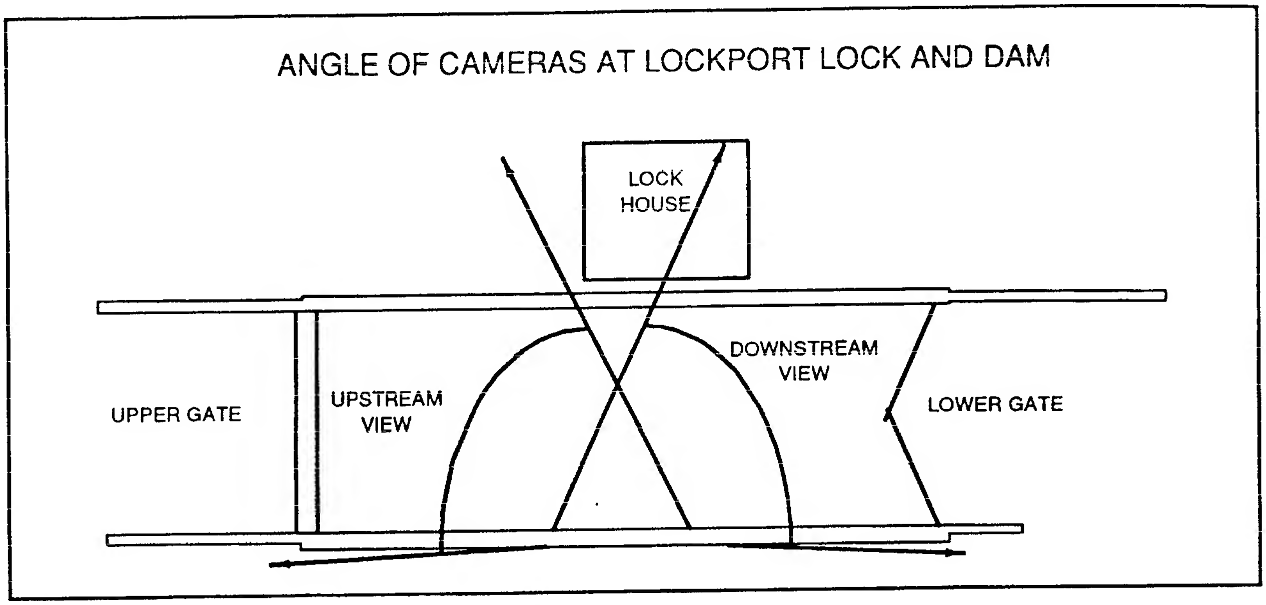

Figure 25. Lock monitoring at Lockport Lock and Dam

Lock and Dam 22 - Mississippi River

Lock and Dam 22 on the Mississippi River was monitored beginning on December 14, 1993, and ending on March 31, 1994. Lock and Dam 22 was selected because of the amount of barge traffic that could be expected from the grain elevators upstream in Quincy, IL. However, due to a railroad bridge span that was being replaced, the section of the Mississippi River above Lock and Dam 22 was closed to river traffic for a period from approximately December 17 to 27, 1994. Anticipating this, most of the expected barge traffic had avoided this delay and moved a majority of the grain south a few weeks before the monitoring could be set up.

With a limited amount of traffic to be expected, the tapes from Lock and Dam 22 could only be utilized to establish the fluctuations of the chamber pools in a nonoperational lock during the winter months. This gave great insight in determining a basis as to what occurs during the winter months when river traffic is at a minimum. This though will be typical of most of the locks and dams in the UMR-IWW navigation area.

The general location of the camera setup for Lock and Dam 22 is shown in Figure 26.

Results

Barge impacts

The impact of barges on chamber walls was determined for various locations in a lock chamber. These locations were located at upper pool,

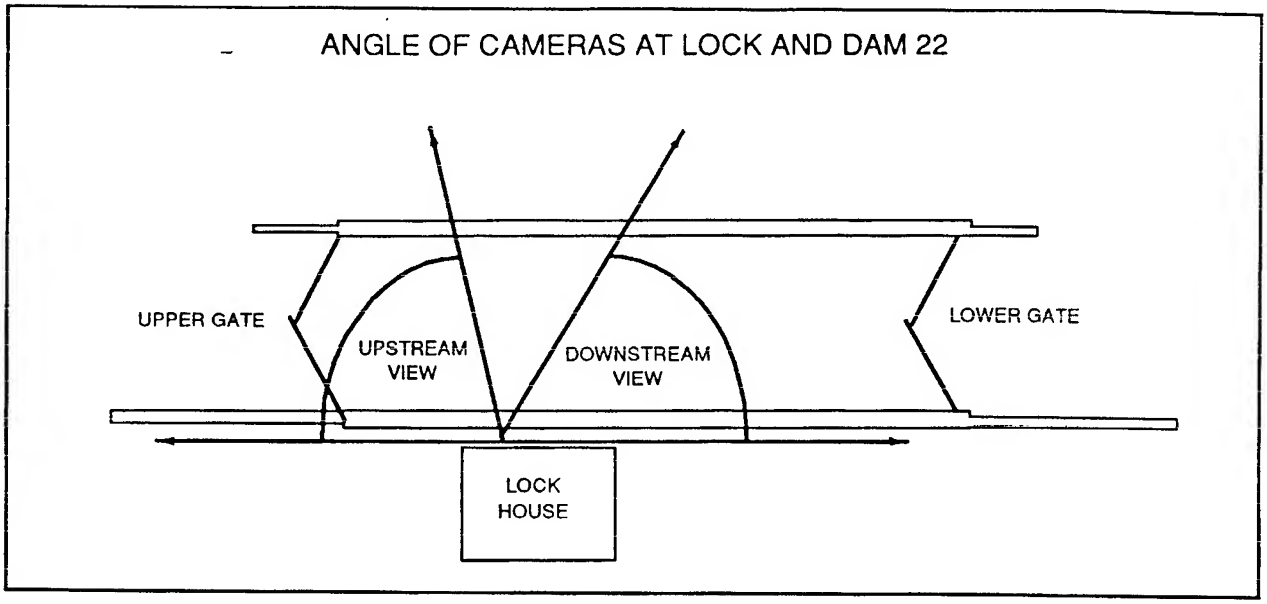

Figure 26. Lock monitoring at Lock and Dam 22

around the gates (both lower and upper and limited to two monoliths into lock chamber), lock walls during emptying and filling of the lock, and at lower pool. However, only the impacts at upper pool and around the upper gate will be presented at this time for use in the probabilistic model by Patev et al.[1]

The determination if a barge impacted the lock wall was based either on a continuous rub along the lock wall by a barge or a single "bump" of the barge against the lock wall. Barge impacts were counted during each lockage for each camera view (upstream.and downstream). This counting process allowed for a total number of impacts to represent the total number of impacts in the entire lock chamber at upper pool. The total number of impacts was then averaged over the total number of lockages that occurred during the specified period. In probabilistic model,[1] the number of impacts per lockage is then divided in half to account for the distance of one wall which is 600 ft in length.

The mean value determined from the monitoring for the number of impacts per lockage was 2.52 impacts per lockage or 1.26 impacts per wall. This statistic was based on a total number of 281 lockages and a total of 709 impacts on the lock chamber over a 7-week period. The standard deviation for the number of impacts was very high, since the distribution of the lockages showed that many lockages had no impacts while some had many. This fact is clearly shown by the frequency distribution and histogram of the number of impacts per lockage. These are shown in Figures 27 and 28, respectively.

[1] Ibid.

Bin	Frequency	Cumulative %
0	88	31.32
1	40	45.55
2	50	63.35
3	29	73.67
4	15	79.00
5	22	86.83
6	9	90.04
7	9	93.24
8	4	94.66
9	4	96.09
10	5	97.86
11	3	98.93
12	0	98.93
13	1	99.29
14	1	99.64
15	1	100.00

Figure 27. Frequency distribution and cumulative percent frequency for number of impacts at Lockport Lock and Dam

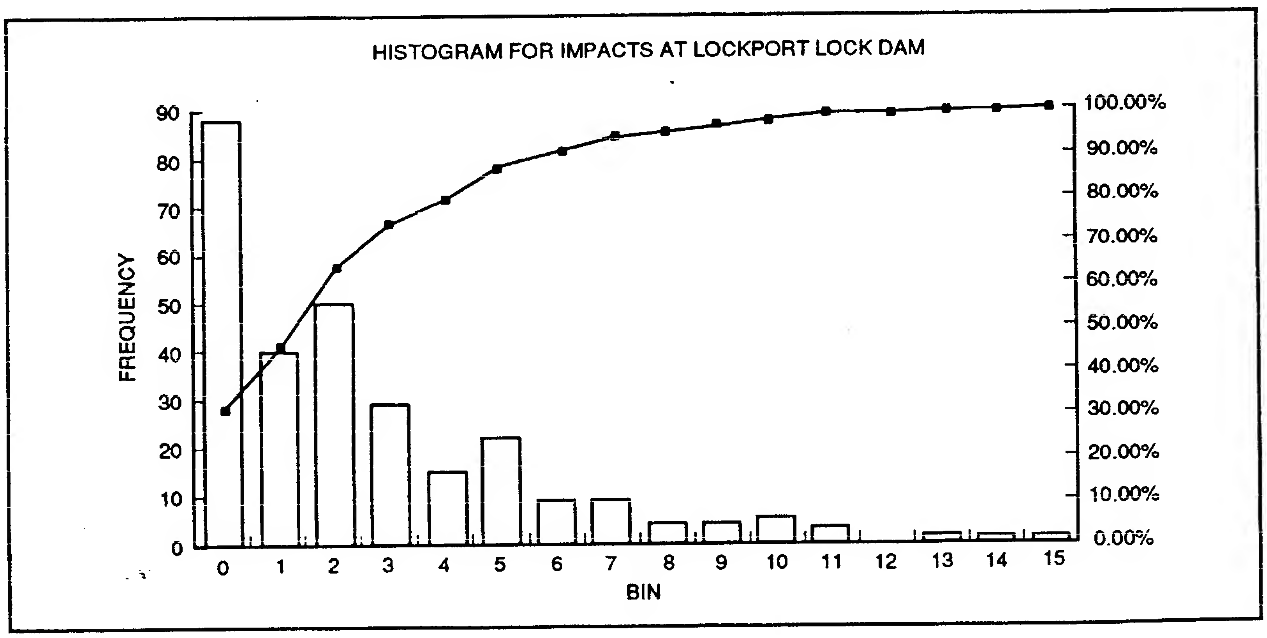

Figure 28. Histogram for number of impacts at Lockport Lock and Dam

Tow velocities

Velocities of tows were investigated at different points in the lock chamber to look at different speeds that could occur in a lock during an impact. The areas highlighted were points that were inside the upper and lower gates (both at time of entry and at time of mooring) and at a point approximately at midchamber. The velocities are also broken into upstream and downstream lockages because the velocities are different due to the effects of the current. These locations are shown in Figure 29.

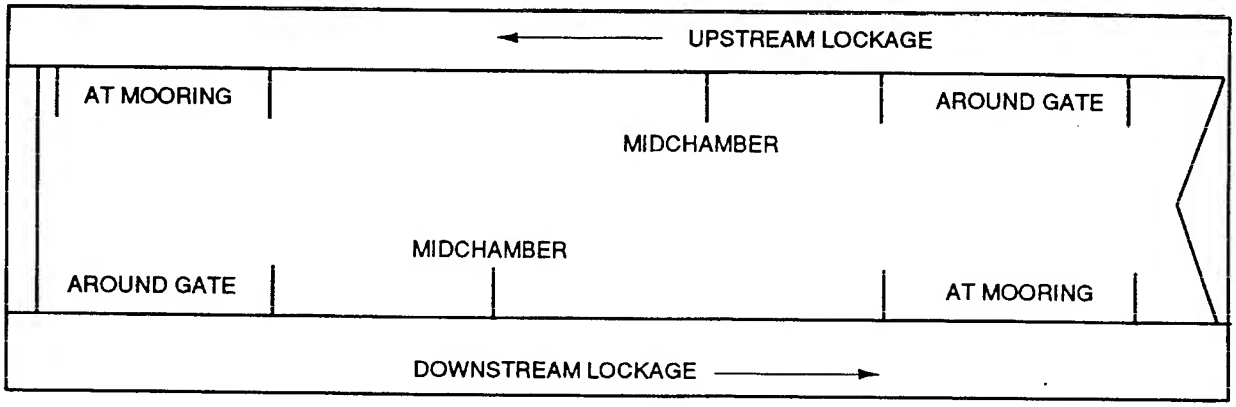

Figure 29. Locations of velocity measurements

The velocities of the tows were determined by using known distances between monoliths or marking on the lock walls and measuring the actual amount of time it took to travel that distance by the time on the tape. The average velocity over that distance was the velocity value that was obtained. The tow velocities were taken from a 4-week period from December 16, 1993, to January 14, 1994, over a total number of 135 lockages.

The average tow velocities and representative coefficients of variation COV) for lockages downstream and upstream are shown in the Table 3.

Table 3
Tow Velocities at Lockport Lock and Dam

	Mean		
Downstream Lockage	**mph**	**ft/s**	**COV**
Around gate	1.88	2.75	0.42
Midchamber	1.79	2.63	0.44
At mooring	0.71	1.04	0.38
Upstream Lockage			
Around gate	1.56	2.29	0.49
Midchamber	1.31	1.91	0.45
At mooring	0.55	0.82	0.49

Fluctuation in pool times

The fluctuations in pool times were determined from the monitoring by analyzing the amount of time that a pool stayed at a continuous level, i.e., upper or lower pool. The times were measured directly from the videotapes from the time when the pool level was reached to the time it started to rise or drop. The pool times determined at the start and end of each videotape, i.e., 5:00 a.m. and 8:00 p.m., were not utilized since it was not known how long the pools were at these levels. This dwell time is crucial to determining the depth that saturation can penetrate the concrete at upper pool. The determination of this value for dwell time will be directly input into the probabilistic model discussed by Patev et al.[1]

The pool times were determined both for Lockport Lock and Dam and Lock and Dam 22 based on actual monitored field times. The actual field times for Lockport are applicable to a lock that is generally operational during the winter months. The actual field times for Lock and Dam 22 are applicable to a nonoperational lock that is at a slowdown down for the winter months. Each location tends to have a different distribution of times at upper pool. This again determines the actual dwell time that the concrete can saturate.

There are other factors that could assist in determining the dwell time. These may be known operational procedures that occur at a lock with the pools. For example, at Lockport the operational procedure during the winter in a slowdown period is to cycle the pools every 2 hours to keep the oil from freezing. A factor like this could be used as a reasonable basis for the value of the dwell time.

The pool time for Lockport was based on 216 upper pool observations and 219 lower pool observations. The pool times for Lock and Dam 22 were based on 142 upper pool observations and 181 lower pool observations. The values for the mean pool times for each lock are shown in Table 4.

Table 4
Pool Times at Lockport Lock and Dam and Lock and Dam 22

Lockport	Min	Hr
Upper pool	93.04	1.62
Lower pool	71.76	1.19
Lock and Dam 22		
Upper pool	71.71	1.19
Lower pool	245.6	4.09

[1] Ibid.

The standard deviations for the pool times are very large compared to the mean values. This is attributable to the distribution of the observations of the pool times. The frequency distributions and histograms for both locks and dams are shown in Figures 30 through 35.

Histogram Data for Lower Pool Times at Lockport

Bin	Frequency	Cumulative %
20	23	10.65
40	61	38.89
60	48	61.11
80	24	72.22
100	11	77.31
120	13	83.33
140	9	87.50
160	4	89.35
180	2	90.28
200	13	96.30
300	7	99.54
400	1	100.00
500	0	100.00
600	0	100.00

Histogram Data for Upper Pool Times at Lockport

Bin	Frequency	Cumulative %
20	44	20.37
40	53	44.91
60	41	63.89
80	20	73.15
100	13	79.17
120	7	82.41
140	7	85.65
160	6	88.43
180	2	89.35
200	10	93.98
300	7	97.22
400	3	98.61
500	3	100.00
600	0	100.00

Figure 30. Frequency distributions for upper and lower pool times at Lockport Lock and Dam

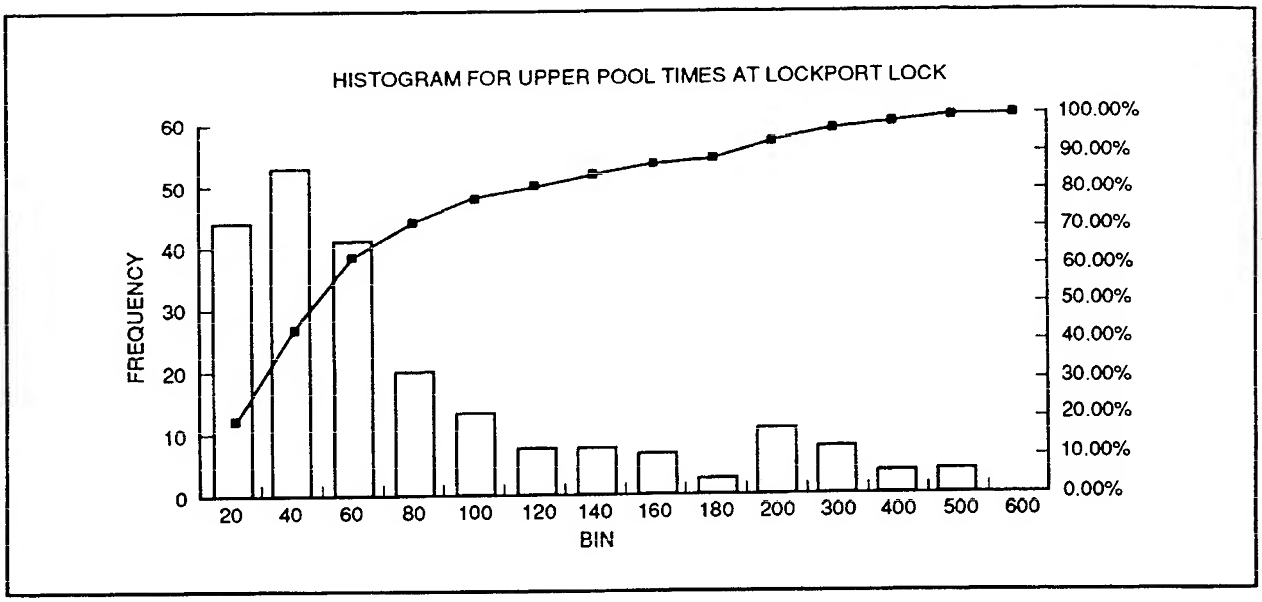

Figure 31. Histogram of upper pool times at Lockport Lock and Dam

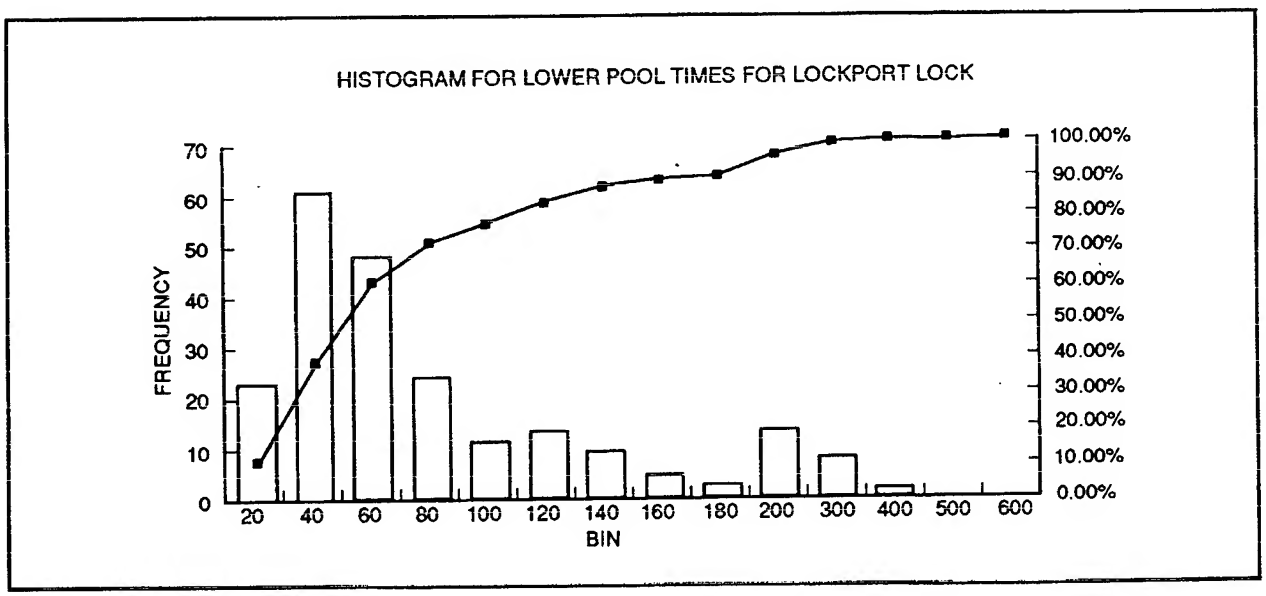

Figure 32. Histogram of lower pool times at Lockport Lock and Dam

Histogram Data for Lower Pool Times at Lock and Dam 22

Bin	Frequency	Cumulative %
20	23	14.02
40	10	20.12
60	6	23.78
80	9	29.27
100	28	46.34
200	32	65.85
300	20	78.05
400	11	84.76
500	6	88.41
600	9	93.90
700	2	95.12
800	4	97.56
900	4	100.00

Histogram Data for Upper Pool Times at Lock and Dam 22

Bin	Frequency	Cumulative %
20	45	44.12
40	16	59.80
60	10	69.61
80	5	74.51
100	15	89.22
200	3	92.16
300	2	94.12
400	3	97.06
500	2	99.02
600	0	99.02
700	0	99.02
800	1	100.00
900	0	100.00

Figure 33. Frequency distributions for upper and lower pool times at Lock and Dam 22

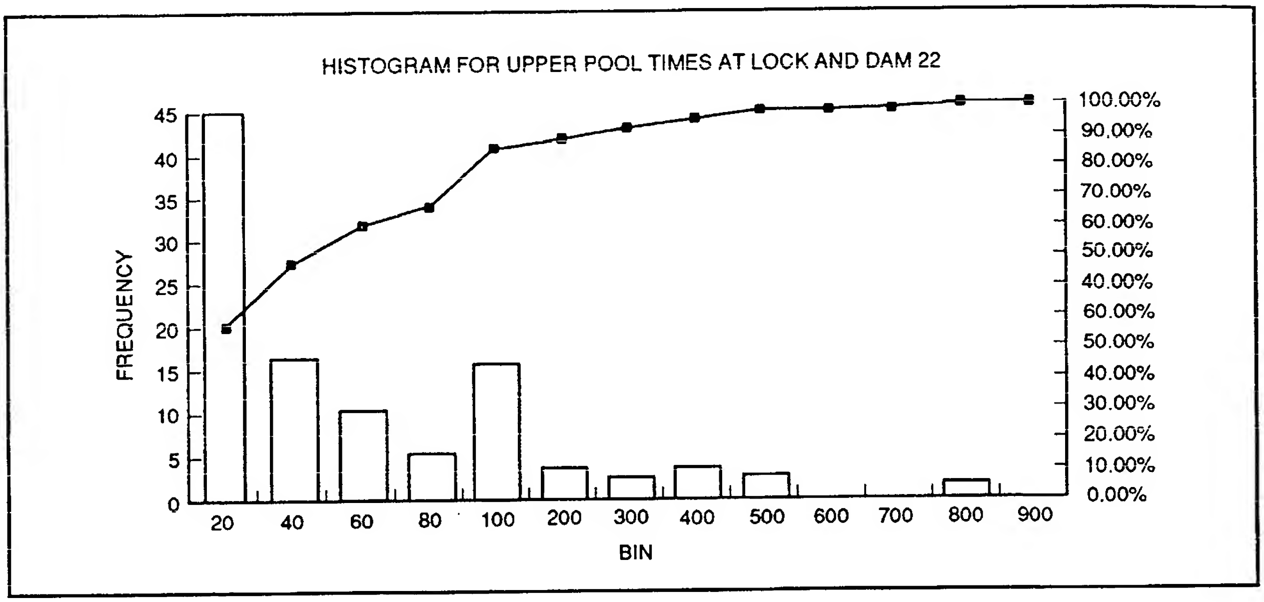

Figure 34. Histogram of upper pool times at Lock and Dam 22

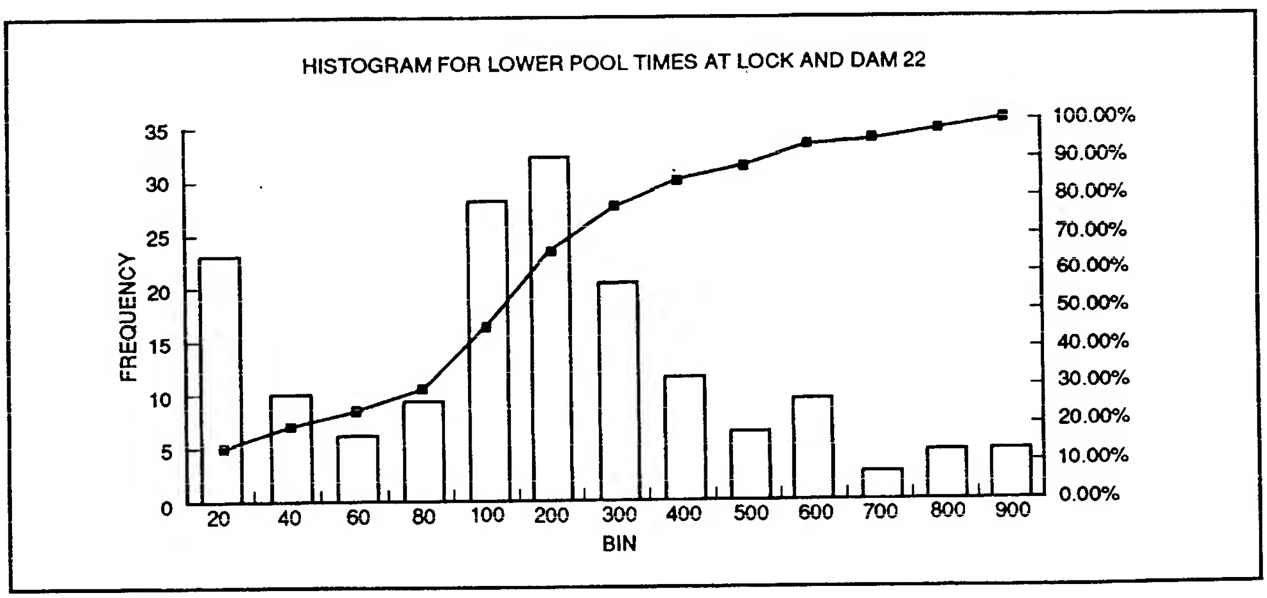

Figure 35. Histogram of lower pool times at Lock and Dam 22

Lockages for ice

Winter weather directly affects the number of loading cycles for fatigue assessment of miter gates because some locks are completely closed to river traffic during the winter months because of ice buildup on the river, and no loading cycles occur during the winter. Other locks are operated year-round and experience buildup of ice in the upper approach regions of locks. Sometimes, miter gates are operated for the purpose of passing ice flows to reduce ice buildup in the upper approach and to relieve any pressure on the gates. The loading cycles for managing the ice flow are usually not recorded in operational logs.

The daily hardware cycles can be computed and adjusted for ice hardware cycles (Ayyub et al.).[1] A hardware cycle is a mechanical emptying or filling of a lock chamber. The adjustment for the ice lockages was based on time-lapsed videotapes in the winter months of 1993-1994 for Lock and Dam 22 and Lock and Dam 25. The time-lapse videotapes showed 63 and 75 ice lockages, respectively, over periods of 77 and 65 days, respectively. Therefore, an average of one ice lockage per day can be added to the computed lockage cuts, and similarly, two ice hardware cycles per day were added to the computed hardware cycles. However, this is true only for the months of January and February of each year, since this is when the river is frozen over and ice jams need to be flushed through the lock's chamber. These unrecorded loading cycles can contribute up to as many as 6,000 additional hardware cycles over the lifetime of a miter gate, i.e., 50 years. These unrecorded lockages were not previously accounted for in the fatigue reliability assessment of the miter gates.

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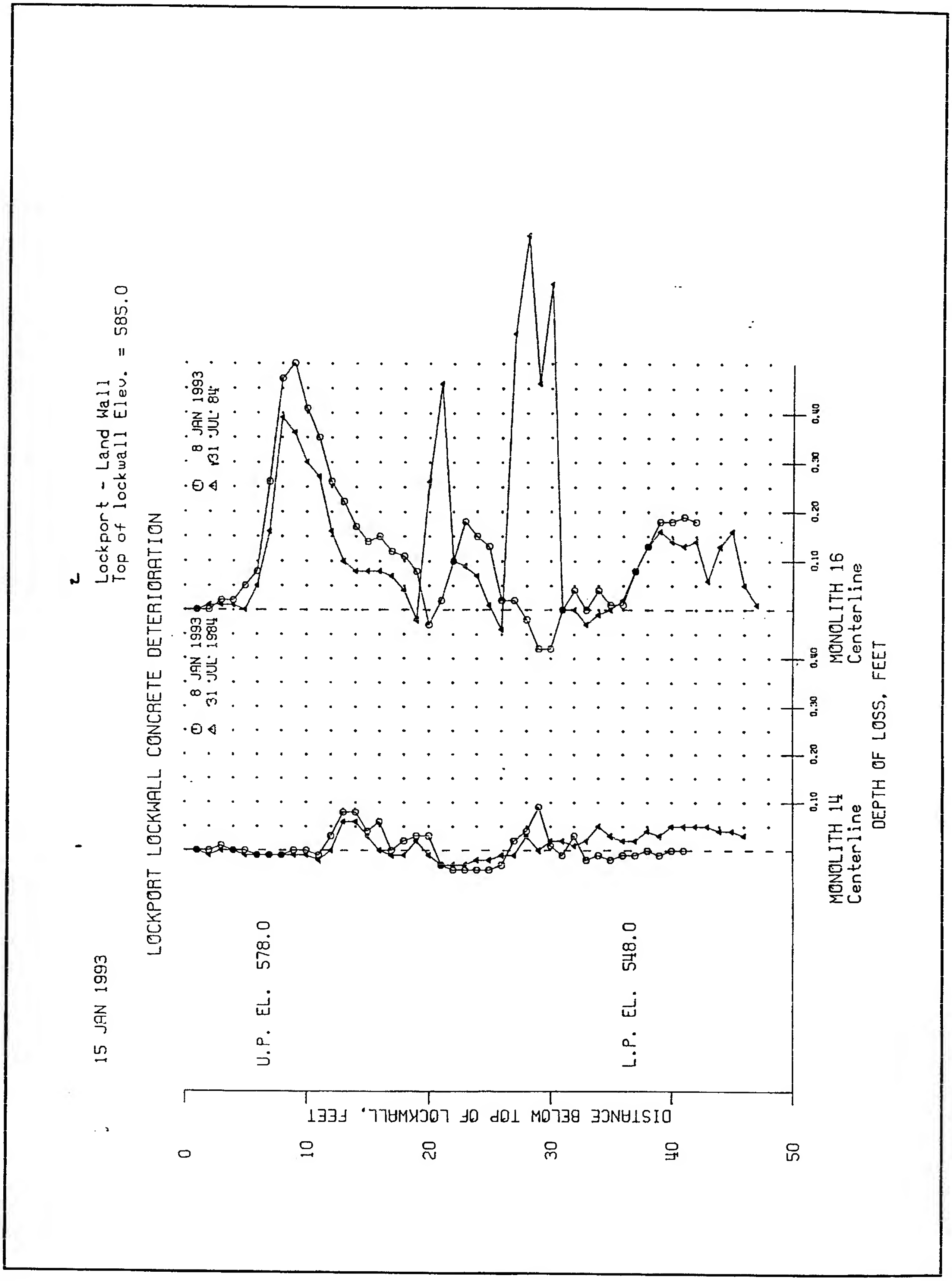
[1] B. M. Ayyub, M. P. Kaminsky, R. C. Patev, and M. A. Leggett. "Loading cycles for the fatigue reliability analysis of miter gates," Technical Report ITL-95-12, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

4 Conclusions and Recommendations

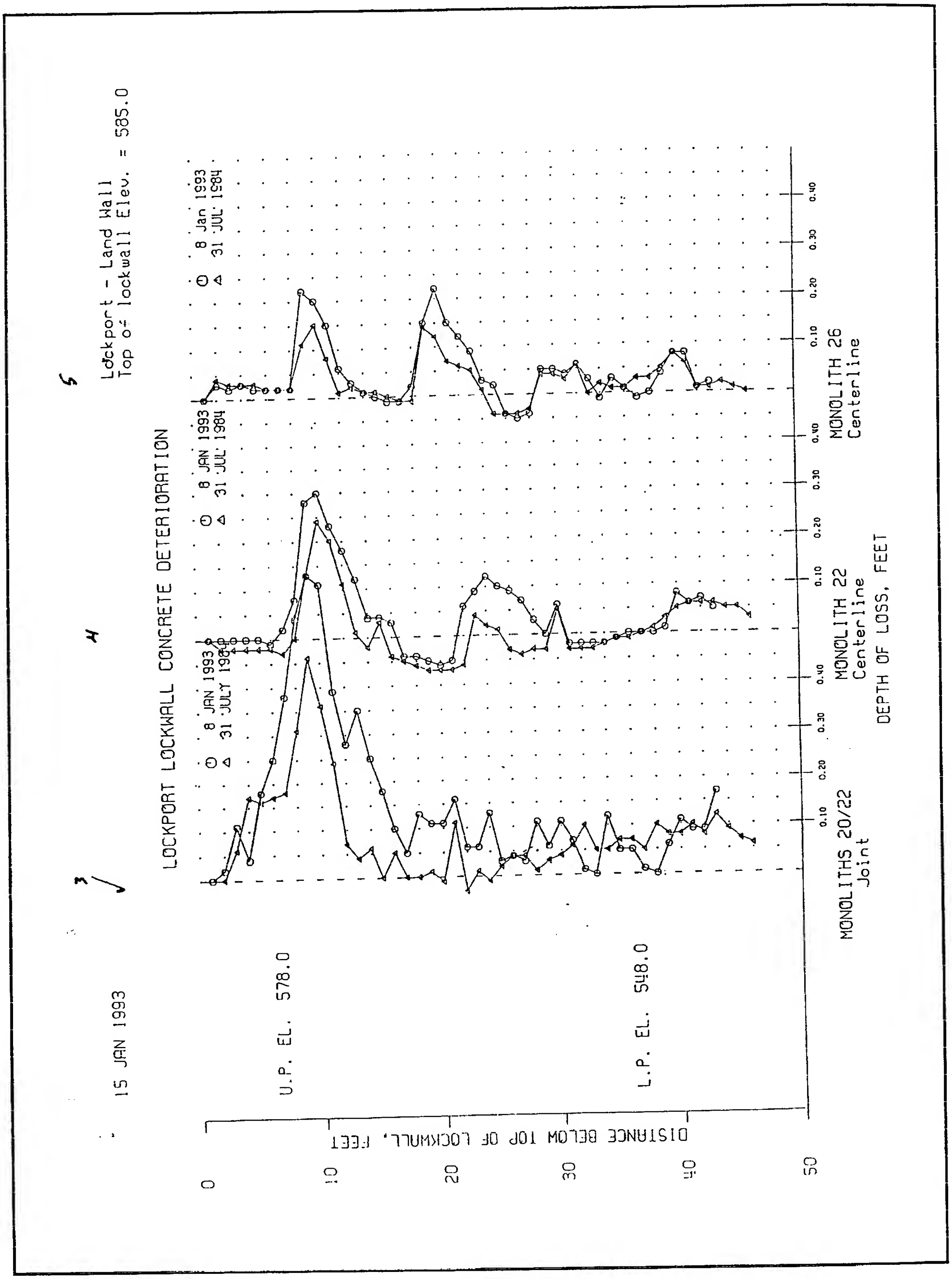
The data collected as part of this study were crucial in developing the proper constraints for the UMR-IWW concrete deterioration model. Without the collection of data from this study, the model may have predicted a single value for the depth of concrete loss without recognizing the pattern of loss that occurs in the field. Since the UMR-IWW deterioration model was a first iteration in the development process, results from this study can help to refine the direction of future work as more data are collected.

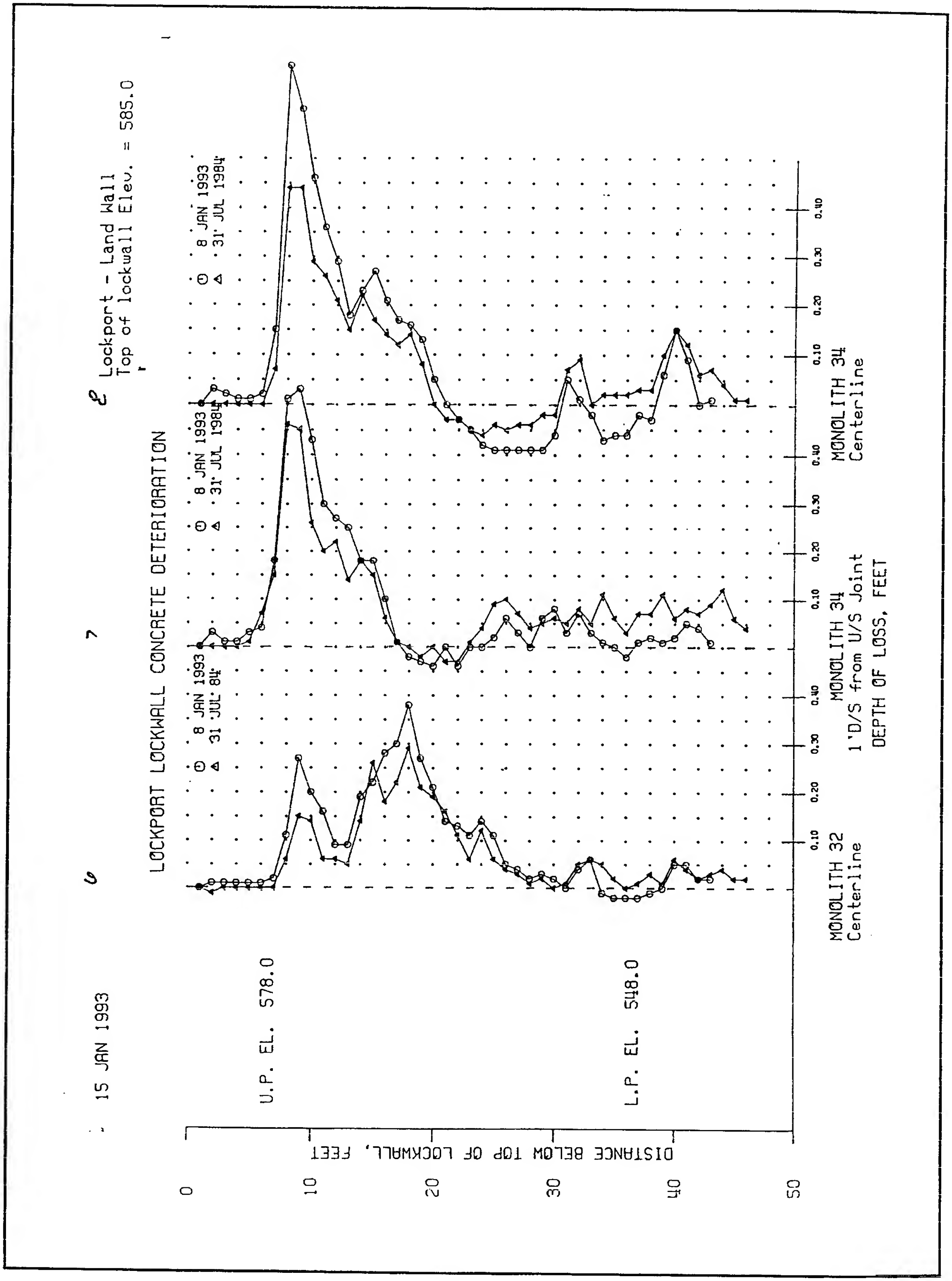
This study also greatly enhanced our knowledge of collecting physical field data. Typically, the collection of physical field data is an expensive and tedious work effort. This study resulted in a substantial reduction in cost and manpower levels required to collect the variety of physical field data that were cataloged. These videotapes have also been used to investigate other physical field data such as locking of ice and debris and hydraulic flow conditions of lock approaches.

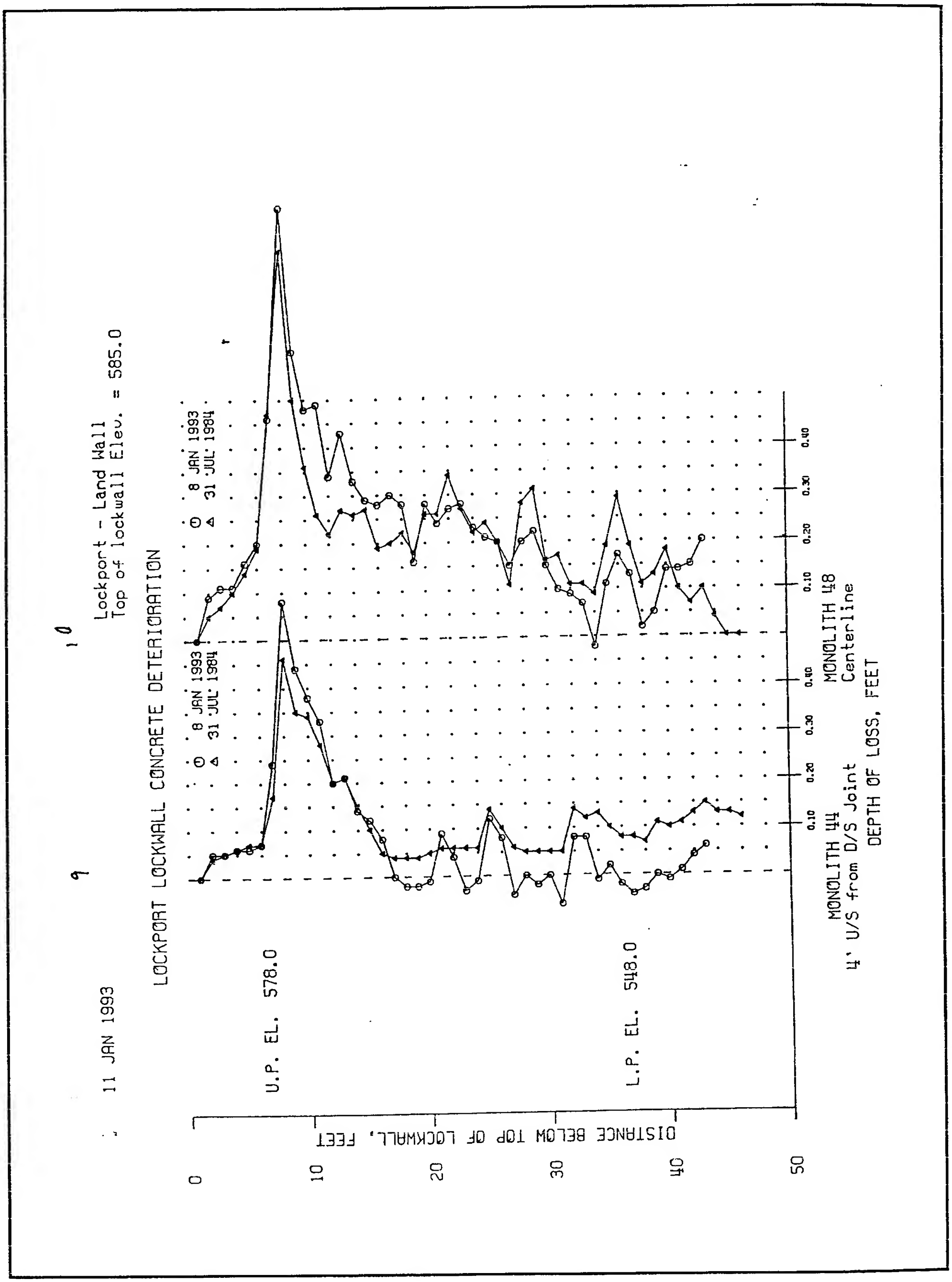
Appendix A
Field Logs for Lockport Loss Measurements

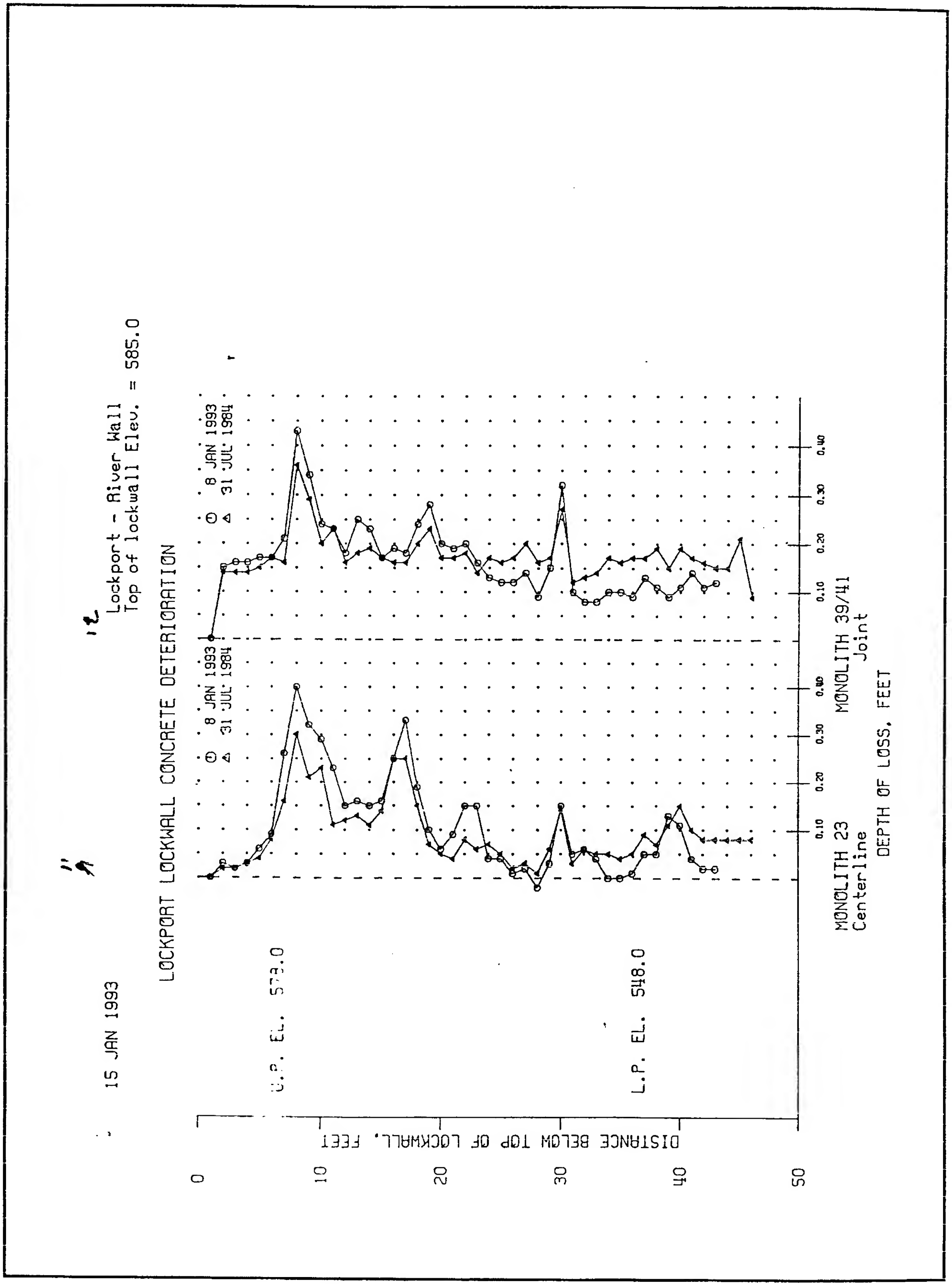


15 JAN 1993
LOCKPORT LOCKWALL CONCRETE DETERIORATION
Lockport - Land Wall
Top of lockwall Elev. = 585.0
8 JAN 1993
31 JUL 1984
8 JAN 1993
31 JUL 84
U.P. EL. 578.0
L.P. EL. 548.0
DISTANCE BELOW TOP OF LOCKWALL, FEET
0
10
20
30
40
50
0.10
0.20
0.30
0.40
MONOLITH 14
Centerline
MONOLITH 16
Centerline
DEPTH OF LOSS, FEET

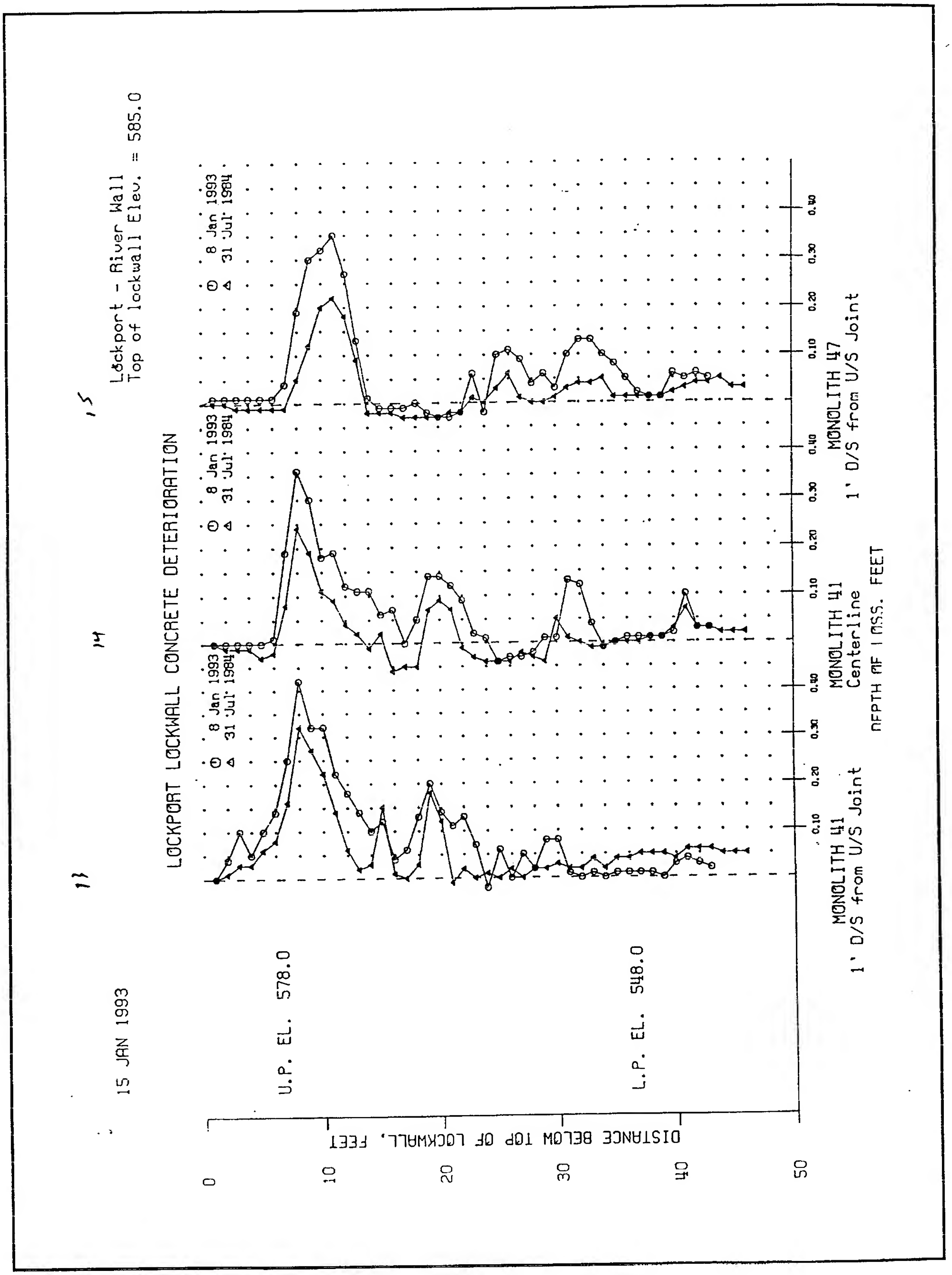

LOCKPORT LOCKWALL CONCRETE DETERIORATION
Lockport - Land Wall
Top of lockwall Elev. = 585.0
15 JAN 1993
U.P. EL. 578.0
L.P. EL. 548.0
3
4
5
8 JAN 1993
31 JULY 1984
8 JAN 1993
31 JUL 1984
8 Jan 1993
31 JUL 1984
0
10
20
30
40
50
DISTANCE BELOW TOP OF LOCKWALL, FEET
0.10
0.20
0.30
0.40
MONOLITHS 20/22
Joint
MONOLITH 22
Centerline
MONOLITH 26
Centerline
DEPTH OF LOSS, FEET


15 JAN 1993
LOCKPORT LOCKWALL CONCRETE DETERIORATION
Lockport - Land Wall
Top of lockwall Elev. = 585.0
U.P. EL. 578.0
L.P. EL. 548.0
8 JAN 1993
31 JUL 84
8 JAN 1993
31 JUL 1984
8 JAN 1993
31 JUL 1984
MONOLITH 32
Centerline
MONOLITH 34
1'D/S from U/S Joint
MONOLITH 34
Centerline
DEPTH OF LOSS, FEET
0.10
0.20
0.30
0.40
DISTANCE BELOW TOP OF LOCKWALL, FEET
0
10
20
30
40
50


11 JAN 1993
LOCKPORT LOCKWALL CONCRETE DETERIORATION
Lockport - Land Wall
Top of lockwall Elev. = 585.0
U.P. EL. 578.0
L.P. EL. 548.0
Θ 8 JAN 1993
Δ 31 JUL 1984
Θ 8 JAN 1993
Δ 31 JUL 1984
0.10
0.20
0.30
0.40
0.10
0.20
0.30
0.40
MONOLITH 44
4' U/S from D/S Joint
MONOLITH 48
Centerline
DEPTH OF LOSS, FEET
DISTANCE BELOW TOP OF LOCKWALL, FEET
0
10
20
30
40
50



15 JAN 1993
LOCKPORT LOCKWALL CONCRETE DETERIORATION
Lockport - River Wall
Top of lockwall Elev. = 585.0
8 JAN 1993
31 JUL 1984
L.P. EL. 548.0
MONOLITH 23
Centerline
MONOLITH 39/41
Joint
DEPTH OF LOSS, FEET
DISTANCE BELOW TOP OF LOCKWALL, FEET
0
10
20
30
40
50
0.10
0.20
0.30
0.40


LOCKPORT LOCKWALL CONCRETE DETERIORATION
Lockport - River Wall
Top of lockwall Elev. = 585.0
15 JAN 1993
U.P. EL. 578.0
L.P. EL. 548.0
8 Jan 1993
31 Jul 1984
13
14
15
MONOLITH 41
1' D/S from U/S Joint
MONOLITH 41
Centerline
MONOLITH 47
1' D/S from U/S Joint
DEPTH OF LOSS, FEET
DISTANCE BELOW TOP OF LOCKWALL, FEET
0.10
0.20
0.30
0.40
0
10
20
30
40
50

****
LOCKPORT CONCRETE LOSS SURVEYS IN JUL 84 AND JAN 93
****

LAND WALL
MONOLITH 14, CENTERLINE

ELEV	LOSS 84 (FT)	LOSS 93 (FT)
584	0.000	0.000
583	-0.010	0.000
582	0.000	0.010
581	0.000	0.000
580	-0.010	0.000
579	-0.010	-0.010
578	-0.010	-0.010
577	-0.010	-0.010
576	-0.010	0.000
575	-0.010	0.000
574	-0.020	-0.010
573	0.000	-0.030
572	0.060	0.080
571	0.060	0.080
570	0.030	0.040
569	0.000	0.060
568	-0.010	0.000
567	-0.010	0.020
566	0.030	0.030
565	-0.010	0.030
564	-0.030	-0.050
563	-0.030	-0.040
562	-0.030	-0.040
561	-0.020	-0.040
560	-0.020	-0.040
559	-0.010	-0.030
558	-0.010	0.020
557	0.030	0.040
556	0.000	0.100
555	0.020	0.010
554	0.020	-0.010
553	0.010	0.030
552	0.020	-0.020
551	0.050	-0.010
550	0.030	-0.020
549	0.020	-0.010
548	0.020	-0.010
547	0.040	0.000
546	0.030	-0.010
545	0.050	0.000
544	0.050	0.000
543	0.050	
542	0.050	
541	0.040	
540	0.040	
539	0.030	
AVERAGE	0.011	0.004
MAX	0.060	0.100

LAND WALL
MONOLITH 16, CENTERLINE

ELEV	LOSS 84 (FT)	LOSS 93 (FT)
584	0.000	0.000
583	0.010	0.000
582	0.010	0.020
581	0.010	0.020
580	0.000	0.050
579	0.050	0.080
578	0.160	0.260
577	0.400	0.470
576	0.360	0.500
575	0.300	0.410
574	0.270	0.350
573	0.160	0.260
572	0.100	0.220
571	0.080	0.170
570	0.080	0.140
569	0.080	0.150
568	0.070	0.120
567	0.040	0.110
566	-0.020	0.080
565	-0.100	-0.030
564	-0.080	0.020
563	0.100	0.100
562	0.090	0.170
561	0.070	0.150
560	0.010	0.130
559	-0.040	0.020
558	-0.070	0.020
557	-0.050	-0.020
556	-0.080	-0.080
555	-0.060	-0.080
554	0.000	0.000
553	0.000	0.040
552	-0.030	0.000
551	-0.010	0.040
550	0.000	0.010
549	0.020	0.010
548	0.080	0.080
547	0.030	0.130
546	0.160	0.180
545	0.140	0.180
544	0.130	0.190
543	0.140	0.180
542	0.060	
541	0.130	
540	0.160	
539	0.050	
AVERAGE	0.065	0.115
MAX	0.400	0.500

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LOCKPORT CONCRETE LOSS SURVEYS IN JUL 84 AND JAN 93

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LAND WALL
MONOLITHS 20/22 JOINT

ELEV	LOSS 84 (FT)	LOSS 93 (FT)
584	0.000	0.000
583	0.000	0.020
582	0.060	0.110
581	0.170	0.040
580	0.160	0.180
579	0.170	0.250
578	0.180	0.380
577	0.310	0.540
576	0.460	0.630
575	0.360	0.610
574	0.240	0.380
573	0.070	0.280
572	0.050	0.350
571	0.060	0.250
570	0.000	0.180
569	0.050	0.100
568	0.000	0.050
567	0.000	0.130
566	0.010	0.110
565	-0.010	0.110
564	0.110	0.160
563	-0.030	0.060
562	0.010	0.060
561	-0.010	0.130
560	0.020	0.030
559	0.040	0.040
558	0.040	0.030
557	0.010	0.110
556	0.030	0.050
555	0.040	0.110
554	0.050	0.060
553	0.100	0.010
552	0.050	0.000
551	0.050	0.120
550	0.070	0.050
549	0.070	0.050
548	0.050	0.010
547	0.100	0.000
546	0.080	0.060
545	0.080	0.110
544	0.110	0.090
543	0.090	0.090
542	0.120	0.170
541	0.090	
540	0.070	
539	0.060	
	=====	=====
AVERAGE	0.083	0.147
MAX	0.460	0.630

LAND WALL
MONOLITH 22, CENTERLINE

ELEV	LOSS 84 (FT)	LOSS 93 (FT)
584	0.000	0.000
583	-0.020	0.000
582	-0.020	0.000
581	-0.020	0.000
580	-0.020	0.000
579	-0.020	-0.010
578	-0.030	0.020
577	0.000	0.080
576	0.130	0.270
575	0.240	0.300
574	0.200	0.230
573	0.120	0.180
572	0.020	0.120
571	-0.020	0.040
570	0.030	0.040
569	-0.040	0.030
568	-0.050	-0.040
567	-0.060	-0.040
566	-0.070	-0.050
565	-0.070	-0.060
564	-0.060	-0.050
563	-0.060	0.060
562	0.040	0.080
561	0.020	0.120
560	0.010	0.100
559	-0.030	0.090
558	-0.040	0.070
557	-0.030	0.030
556	-0.030	0.000
555	0.050	0.050
554	-0.030	-0.020
553	-0.030	-0.020
552	-0.030	-0.020
551	-0.020	-0.020
550	-0.010	-0.010
549	-0.010	-0.010
548	0.000	0.000
547	0.010	0.000
546	0.030	0.010
545	0.050	0.080
544	0.060	0.050
543	0.060	0.060
542	0.060	0.040
541	0.050	
540	0.050	
539	0.030	
	=====	=====
	0.010	0.042
	0.240	0.300

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LOCKPORT CONCRETE LOSS SURVEYS IN JUL 84 AND JAN 93

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LAND WALL
MONOLITH 26, CENTERLINE

ELEV	LOSS 84 (FT)	LOSS 93 (FT)
584	0.000	0.000
583	0.040	0.030
582	0.030	0.020
581	0.030	0.030
580	0.030	0.020
579	0.020	0.020
578	0.020	0.020
577	0.020	0.020
576	0.110	0.220
575	0.150	0.200
574	0.080	0.150
573	0.010	0.060
572	0.020	0.030
571	0.010	0.010
570	0.010	0.000
569	0.000	-0.010
568	-0.010	-0.010
567	-0.010	0.020
566	0.140	0.150
565	0.120	0.220
564	0.060	0.150
563	0.060	0.120
562	0.050	0.100
561	0.010	0.030
560	-0.040	0.020
559	-0.040	-0.040
558	-0.040	-0.050
557	-0.030	-0.040
556	0.030	0.050
555	0.030	0.050
554	0.020	0.040
553	0.060	0.060
552	0.000	0.030
551	0.020	-0.010
550	0.010	0.030
549	0.010	0.010
548	0.030	-0.010
547	0.030	0.000
546	0.050	0.040
545	0.080	0.080
544	0.060	0.080
543	0.010	0.010
542	0.010	0.020
541	0.020	
540	0.010	
539	0.000	
AVERAGE	0.029	0.048
MAX	0.150	0.220

LAND WALL
MONOLITH 32, CENTERLINE

ELEV	LOSS 84 (FT)	LOSS 93 (FT)
584	0.000	0.000
583	-0.010	0.010
582	0.000	0.010
581	0.000	0.010
580	0.000	0.010
579	0.000	0.010
578	0.000	0.020
577	0.060	0.110
576	0.150	0.260
575	0.140	0.200
574	0.060	0.160
573	0.060	0.090
572	0.050	0.090
571	0.140	0.190
570	0.260	0.230
569	0.180	0.280
568	0.220	0.300
567	0.280	0.380
566	0.210	0.270
565	0.190	0.210
564	0.160	0.140
563	0.110	0.130
562	0.060	0.110
561	0.120	0.140
560	0.060	0.110
559	0.040	0.050
558	0.030	0.040
557	0.010	0.020
556	0.030	0.030
555	0.000	0.020
554	0.010	0.000
553	0.050	0.040
552	0.060	0.060
551	0.050	-0.010
550	0.020	-0.020
549	0.000	-0.020
548	0.010	-0.020
547	0.030	-0.010
546	0.010	0.000
545	0.050	0.050
544	0.040	0.050
543	0.020	0.020
542	0.030	0.020
541	0.040	
540	0.020	
539	0.020	
AVERAGE	0.067	0.088
MAX	0.280	0.380

LOCKPORT CONCRETE LOSS SURVEYS IN JUL 84 AND JAN 93

LAND WALL
MONOLITH 34, 1' DS OF US JT

ELEV	LOSS 84 (FT)	LOSS 93 (FT)
584	0.000	0.000
583	0.000	0.030
582	0.000	0.010
581	0.000	0.010
580	0.010	0.030
579	0.070	0.040
578	0.150	0.180
577	0.460	0.510
576	0.450	0.530
575	0.260	0.430
574	0.200	0.300
573	0.220	0.270
572	0.140	0.250
571	0.180	0.180
570	0.150	0.180
569	0.060	0.100
568	0.010	0.010
567	0.000	-0.020
566	-0.020	-0.030
565	0.000	-0.040
564	-0.030	0.000
563	-0.030	-0.040
562	0.010	0.000
561	0.040	0.000
560	0.090	0.020
559	0.100	0.060
558	0.070	0.030
557	0.040	0.000
556	0.050	0.060
555	0.060	0.080
554	0.050	0.030
553	0.080	0.070
552	0.050	0.030
551	0.110	0.010
550	0.050	0.000
549	0.030	-0.020
548	0.070	0.010
547	0.070	0.020
546	0.110	0.010
545	0.060	0.020
544	0.070	0.050
543	0.060	0.040
542	0.080	0.010
541	0.120	
539	0.040	
AVERAGE	0.083	0.080
MAX	0.460	0.530

LAND WALL
MONOLITH 34, CENTERLINE

ELEV	LOSS 84 (FT)	LOSS 93 (FT)
584	0.000	0.000
583	0.000	0.030
582	0.000	0.020
581	0.000	0.010
580	0.000	0.010
579	0.000	0.020
578	0.070	0.150
577	0.440	0.700
576	0.440	0.600
575	0.290	0.460
574	0.260	0.360
573	0.210	0.290
572	0.150	0.180
571	0.220	0.230
570	0.170	0.270
569	0.140	0.210
568	0.120	0.170
567	0.140	0.160
566	0.080	0.140
565	0.000	0.050
564	-0.030	0.000
563	-0.030	-0.030
562	-0.050	-0.050
561	-0.060	-0.080
560	-0.040	-0.090
559	-0.050	-0.090
558	-0.040	-0.090
557	-0.040	-0.090
556	-0.020	-0.090
555	-0.020	-0.060
554	0.070	0.050
553	0.090	0.010
552	0.000	-0.020
551	0.020	-0.070
550	0.020	-0.060
549	0.020	-0.060
548	0.030	-0.020
547	0.030	-0.030
546	0.100	0.060
545	0.150	0.150
544	0.120	0.090
543	0.060	0.000
542	0.070	0.010
541	0.040	
539	0.010	
	0.069	0.081
	0.440	0.700

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LOCKPORT CONCRETE LOSS SURVEYS IN JUL 84 AND JAN 93

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LAND WALL
MONOLITH 44, 4' US OF DS JT

ELEV	LOSS 84 (FT)	LOSS 93 (FT)
584	0.000	0.000
583	0.040	0.050
582	0.050	0.050
581	0.060	0.060
580	0.070	0.060
579	0.070	0.070
578	0.170	0.240
577	0.460	0.580
576	0.350	0.440
575	0.340	0.380
574	0.280	0.330
573	0.200	0.200
572	0.210	0.210
571	0.150	0.140
570	0.100	0.120
569	0.050	0.080
568	0.040	0.000
567	0.040	-0.020
566	0.040	-0.020
565	0.050	-0.010
564	0.060	0.090
563	0.060	0.040
562	0.060	-0.030
561	0.060	-0.010
560	0.140	0.120
559	0.100	0.080
558	0.060	-0.050
557	0.050	0.000
556	0.050	-0.020
555	0.050	0.000
554	0.050	-0.070
553	0.140	0.080
552	0.120	0.080
551	0.130	-0.010
550	0.100	0.020
549	0.080	-0.020
548	0.080	-0.030
547	0.070	-0.020
546	0.110	0.000
545	0.100	-0.010
544	0.110	0.010
543	0.130	0.040
541	0.130	
540	0.130	
539	0.120	
AVERAGE	0.113	0.077
MAX	0.460	0.580

LAND WALL
MONOLITH 48, CENTERLINE

ELEV	LOSS 84 (FT)	LOSS 93 (FT)
584	0.000	0.000
583	0.050	0.090
582	0.070	0.110
581	0.100	0.110
580	0.140	0.160
579	0.190	0.200
578	0.460	0.450
577	0.800	0.890
576	0.500	0.600
575	0.360	0.480
574	0.260	0.490
573	0.220	0.340
572	0.270	0.430
571	0.260	0.330
570	0.270	0.290
569	0.190	0.280
568	0.200	0.300
567	0.220	0.280
566	0.170	0.160
565	0.260	0.280
564	0.260	0.230
563	0.330	0.270
562	0.270	0.280
561	0.220	0.230
560	0.210	0.240
559	0.200	0.200
558	0.110	0.150
557	0.280	0.200
556	0.310	0.210
555	0.160	0.150
554	0.170	0.100
553	0.110	0.090
552	0.110	0.070
551	0.090	-0.020
550	0.190	0.110
549	0.290	0.170
548	0.190	0.120
547	0.110	0.020
546	0.130	0.050
545	0.180	0.140
544	0.100	0.140
543	0.070	0.150
541	0.040	
540	0.000	
539	0.000	
AVERAGE	0.200	0.227
MAX	0.800	0.890

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LOCKPORT CONCRETE LOSS SURVEYS IN JUL 84 AND JAN 93
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RIVER WALL
MONOLITH 23, CENTERLINE

ELEV	LOSS 84 (FT)	LOSS 93 (FT)
584	0.000	0.000
583	0.020	0.030
582	0.020	0.020
581	0.030	0.030
580	0.040	0.060
579	0.080	0.090
578	0.160	0.260
577	0.300	0.400
576	0.210	0.320
575	0.230	0.290
574	0.110	0.230
573	0.120	0.150
572	0.130	0.160
571	0.110	0.150
570	0.140	0.160
569	0.250	0.250
568	0.250	0.330
567	0.150	0.190
566	0.070	0.100
565	0.050	0.060
564	0.040	0.090
563	0.070	0.150
562	0.060	0.150
561	0.070	0.040
560	0.050	0.040
559	0.020	0.010
558	0.030	0.020
557	0.010	-0.020
556	0.050	0.030
555	0.150	0.150
554	0.040	0.050
553	0.060	0.060
552	0.050	0.040
551	0.050	0.000
550	0.040	0.000
549	0.050	0.010
548	0.090	0.050
547	0.070	0.050
546	0.110	0.130
545	0.150	0.110
543	0.080	0.020
542	0.080	0.020
541	0.080	
540	0.080	
539	0.080	
	=====	=====
AVERAGE	0.092	0.105
MAX	0.300	0.400

RIVER WALL
MONOLITH 39/41 JOINT

ELEV	LOSS 84 (FT)	LOSS 93 (FT)
584	0.000	0.000
583	0.140	0.150
582	0.140	0.160
581	0.140	0.160
580	0.150	0.170
579	0.170	0.170
578	0.160	0.210
577	0.360	0.430
576	0.290	0.340
575	0.200	0.240
574	0.230	0.230
573	0.160	0.180
572	0.180	0.250
571	0.190	0.230
570	0.170	0.170
569	0.160	0.190
568	0.160	0.180
567	0.200	0.240
566	0.230	0.280
565	0.170	0.200
564	0.170	0.190
563	0.180	0.200
562	0.140	0.160
561	0.170	0.130
560	0.160	0.110
559	0.170	0.110
558	0.200	0.140
557	0.160	0.090
556	0.170	0.150
555	0.270	0.320
554	0.120	0.100
553	0.130	0.080
552	0.140	0.080
551	0.170	0.100
550	0.160	0.100
549	0.170	0.090
548	0.170	0.130
547	0.190	0.110
546	0.150	0.090
545	0.190	0.110
543	0.160	0.110
542	0.150	0.120
541	0.150	
540	0.210	
539	0.100	
	=====	=====
	0.172	0.166
	0.360	0.430

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LOCKPORT CONCRETE LOSS SURVEYS IN JUL 84 AND JAN 93

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RIVER WALL
MONOLITH 41 1' DS OF US JT

ELEV	LOSS 84 (FT)	LOSS 93 (FT)
584	0.000	0.000
583	0.010	0.040
582	0.030	0.100
581	0.030	0.050
580	0.060	0.100
579	0.070	0.140
578	0.160	0.250
577	0.320	0.420
576	0.270	0.320
575	0.220	0.320
574	0.140	0.220
573	0.060	0.180
572	0.020	0.140
571	0.030	0.100
570	0.150	0.120
569	0.010	0.040
568	0.000	0.060
567	0.030	0.130
566	0.180	0.200
565	0.120	0.140
564	-0.010	0.110
563	0.020	0.130
562	0.000	0.070
561	0.010	-0.020
560	0.000	0.060
559	0.020	0.000
558	0.000	0.050
557	0.020	0.020
556	0.020	0.080
555	0.030	0.080
554	0.020	0.010
553	0.020	0.000
552	0.040	0.010
551	0.020	0.000
550	0.040	0.010
549	0.040	0.010
548	0.050	0.010
547	0.050	0.010
545	0.040	0.040
544	0.060	0.040
543	0.060	0.030
542	0.060	0.020
541	0.050	
540	0.050	
539	0.050	
	=====	=====
AVERAGE	0.059	0.089
MAX	0.320	0.420

RIVER WALL
MONOLITH 41, CENTERLINE

ELEV	LOSS 84 (FT)	LOSS 93 (FT)
584	0.000	0.000
583	-0.010	0.000
582	-0.010	0.000
581	-0.010	0.000
580	-0.030	0.000
579	-0.020	0.010
578	0.080	0.180
577	0.240	0.360
576	0.190	0.300
575	0.110	0.180
574	0.090	0.190
573	0.040	0.120
572	0.020	0.110
571	-0.010	0.110
570	0.020	0.060
569	-0.060	0.070
568	-0.050	0.000
567	-0.050	0.050
566	0.070	0.140
565	0.090	0.140
564	0.070	0.130
563	-0.010	0.090
562	-0.030	0.020
561	-0.040	0.010
560	-0.040	-0.040
559	-0.040	-0.030
558	-0.020	-0.030
557	-0.030	-0.020
556	-0.040	0.010
555	0.050	0.010
554	0.010	0.130
553	0.000	0.120
552	-0.010	0.040
551	-0.010	-0.010
550	0.000	0.000
549	0.000	0.010
548	0.000	0.010
547	0.010	0.010
545	0.030	0.020
544	0.070	0.100
543	0.030	0.030
542	0.030	0.030
541	0.020	
540	0.020	
539	0.020	
	=====	=====
	0.017	0.062
	0.240	0.360

****
LOCKPORT CONCRETE LOSS SURVEYS IN JUL 84 AND JAN 93
****

RIVER WALL
MONOLITH 47 1' DS OF US JT

ELEV	LOSS 84 (FT)	LOSS 93 (FT)
584	0.000	0.000
583	0.000	0.010
582	0.000	0.010
581	-0.010	0.010
580	-0.010	0.010
579	-0.010	0.010
578	-0.010	0.010
577	-0.010	0.040
576	0.050	0.190
575	0.120	0.300
574	0.200	0.320
573	0.220	0.350
572	0.180	0.270
571	0.090	0.130
570	-0.020	0.010
569	-0.020	-0.010
568	-0.020	0.000
567	-0.030	-0.010
566	-0.030	-0.020
565	-0.030	-0.030
564	-0.020	-0.030
563	-0.020	-0.020
562	0.010	0.060
561	0.000	-0.020
560	0.030	0.100
559	0.060	0.110
558	0.010	0.090
557	0.000	0.050
556	0.000	0.060
555	0.010	0.030
554	0.030	0.100
553	0.040	0.130
552	0.040	0.130
551	0.050	0.100
550	0.010	0.080
549	0.010	0.050
548	0.010	0.020
547	0.010	0.010
546	0.010	0.010
545	0.020	0.060
544	0.030	0.050
543	0.040	0.060
542	0.040	0.050
541	0.050	
540	0.030	
539	0.030	
	=====	=====
AVERAGE	0.026	0.067
MAX	0.220	0.350

****

LOCKPORT CONCRETE LOSS SURVEYS IN JUL 84 AND JAN 93

****

LAND WALL - BETWEEN POOLS
MONOLITH 14, CENTERLINE

ELEV	LOSS 84 (FT)	LOSS 93 (FT)
578	-0.010	-0.010
577	-0.010	-0.010
576	-0.010	0.000
575	-0.010	0.000
574	-0.020	-0.010
573	0.000	-0.030
572	0.060	0.080
571	0.060	0.080
570	0.030	0.040
569	0.000	0.060
568	-0.010	0.000
567	-0.010	0.020
566	0.030	0.030
565	-0.010	0.030
564	-0.030	-0.050
563	-0.030	-0.040
562	-0.030	-0.040
561	-0.020	-0.040
560	-0.020	-0.040
559	-0.010	-0.030
558	-0.010	0.020
557	0.030	0.040
556	0.000	0.100
555	0.020	0.010
554	0.020	-0.010
553	0.010	0.030
552	0.020	-0.020
551	0.050	-0.010
550	0.030	-0.020
549	0.020	-0.010
548	0.020	-0.010
AVERAGE	0.005	0.005
MAX	0.060	0.080

LAND WALL - BETWEEN POOLS
MONOLITH 16, CENTERLINE

ELEV	LOSS 84 (FT)	LOSS 93 (FT)
578	0.160	0.260
577	0.400	0.470
576	0.360	0.500
575	0.300	0.410
574	0.270	0.350
573	0.160	0.260
572	0.100	0.220
571	0.080	0.170
570	0.080	0.140
569	0.080	0.150
568	0.070	0.120
567	0.040	0.110
566	-0.020	0.080
565	-0.100	-0.030
564	-0.080	0.020
563	0.100	0.100
562	0.090	0.170
561	0.070	0.150
560	0.010	0.130
559	-0.040	0.020
558	-0.070	0.020
557	-0.050	-0.020
556	-0.080	-0.080
555	-0.060	-0.080
554	0.000	0.000
553	0.000	0.040
552	-0.030	0.000
551	-0.010	0.040
550	0.000	0.010
549	0.020	0.010
548	0.080	0.080
	0.062	0.123
	0.400	0.500

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LOCKPORT CONCRETE LOSS SURVEYS IN JUL 84 AND JAN 93

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LAND WALL - BETWEEN POOLS
MONOLITHS 20/22 JOINT

ELEV	LOSS 84 (FT)	LOSS 93 (FT)
578	0.180	0.380
577	0.310	0.540
576	0.460	0.630
575	0.360	0.610
574	0.240	0.380
573	0.070	0.280
572	0.050	0.350
571	0.060	0.250
570	0.000	0.180
569	0.050	0.100
568	0.000	0.050
567	0.000	0.130
566	0.010	0.110
565	-0.010	0.110
564	0.110	0.160
563	-0.030	0.060
562	0.010	0.060
561	-0.010	0.130
560	0.020	0.030
559	0.040	0.040
558	0.040	0.030
557	0.010	0.110
556	0.030	0.050
555	0.040	0.110
554	0.050	0.060
553	0.100	0.010
552	0.050	0.000
551	0.050	0.120
550	0.070	0.050
549	0.070	0.050
548	0.050	0.010
	=====	=====
AVERAGE	0.080	0.167
MAX	0.460	0.630

LAND WALL - BETWEEN POOLS
MONOLITH 22, CENTERLINE

ELEV	LOSS 84 (FT)	LOSS 93 (FT)
578	-0.030	0.020
577	0.000	0.080
576	0.130	0.270
575	0.240	0.300
574	0.200	0.230
573	0.120	0.180
572	0.020	0.120
571	-0.020	0.040
570	0.030	0.040
569	-0.040	0.030
568	-0.050	-0.040
567	-0.060	-0.040
566	-0.070	-0.050
565	-0.070	-0.060
564	-0.060	-0.050
563	-0.060	0.060
562	0.040	0.080
561	0.020	0.120
560	0.010	0.100
559	-0.030	0.090
558	-0.040	0.070
557	-0.030	0.030
556	-0.030	0.000
555	0.050	0.050
554	-0.030	-0.020
553	-0.030	-0.020
552	-0.030	-0.020
551	-0.020	-0.020
550	-0.010	-0.010
549	-0.010	-0.010
548	0.000	0.000
	=====	=====
	0.005	0.051
	0.240	0.300

LOCKPORT CONCRETE LOSS SURVEYS IN JUL 84 AND JAN 93

LAND WALL - BETWEEN POOLS
MONOLITH 26, CENTERLINE

ELEV	LOSS 84 (FT)	LOSS 93 (FT)
578	0.020	0.020
577	0.020	0.020
576	0.110	0.220
575	0.150	0.200
574	0.080	0.150
573	0.010	0.060
572	0.020	0.030
571	0.010	0.010
570	0.010	0.000
569	0.000	-0.010
568	-0.010	-0.010
567	-0.010	0.020
566	0.140	0.150
565	0.120	0.220
564	0.060	0.150
563	0.060	0.120
562	0.050	0.100
561	0.010	0.030
560	-0.040	0.020
559	-0.040	-0.040
558	-0.040	-0.050
557	-0.030	-0.040
556	0.030	0.050
555	0.030	0.050
554	0.020	0.040
553	0.060	0.060
552	0.000	0.030
551	0.020	-0.010
550	0.010	0.030
549	0.010	0.010
548	0.030	-0.010
AVERAGE	0.029	0.052
MAX	0.150	0.220

LAND WALL - BETWEEN POOLS
MONOLITH 32, CENTERLINE

ELEV	LOSS 84 (FT)	LOSS 93 (FT)
578	0.000	0.020
577	0.060	0.110
576	0.150	0.260
575	0.140	0.200
574	0.060	0.160
573	0.060	0.090
572	0.050	0.090
571	0.140	0.190
570	0.260	0.230
569	0.180	0.280
568	0.220	0.300
567	0.280	0.380
566	0.210	0.270
565	0.190	0.210
564	0.160	0.140
563	0.110	0.130
562	0.060	0.110
561	0.120	0.140
560	0.060	0.110
559	0.040	0.050
558	0.030	0.040
557	0.010	0.020
556	0.030	0.030
555	0.000	0.020
554	0.010	0.000
553	0.050	0.040
552	0.060	0.060
551	0.050	-0.010
550	0.020	-0.020
549	0.000	-0.020
548	0.010	-0.020
	0.091	0.116
	0.280	0.380

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LOCKPORT CONCRETE LOSS SURVEYS IN JUL 84 AND JAN 93
****

LAND WALL - BETWEEN POOLS
MONOLITH 34, 1' DS OF US JT

ELEV	LOSS 84 (FT)	LOSS 93 (FT)
578	0.150	0.180
577	0.460	0.510
576	0.450	0.530
575	0.260	0.430
574	0.200	0.300
573	0.220	0.270
572	0.140	0.250
571	0.180	0.180
570	0.150	0.180
569	0.060	0.100
568	0.010	0.010
567	0.000	-0.020
566	-0.020	-0.030
565	0.000	-0.040
564	-0.030	0.000
563	-0.030	-0.040
562	0.010	0.000
561	0.040	0.000
560	0.090	0.020
559	0.100	0.060
558	0.070	0.030
557	0.040	0.000
556	0.050	0.060
555	0.060	0.080
554	0.050	0.030
553	0.080	0.070
552	0.050	0.030
551	0.110	0.010
550	0.050	0.000
549	0.030	-0.020
548	0.070	0.010
	=====	=====
AVERAGE	0.100	0.103
MAX	0.460	0.530

LAND WALL - BETWEEN POOLS
MONOLITH 34, CENTERLINE

ELEV	LOSS 84 (FT)	LOSS 93 (FT)
578	0.070	0.150
577	0.440	0.700
576	0.440	0.600
575	0.290	0.460
574	0.260	0.360
573	0.210	0.290
572	0.150	0.180
571	0.220	0.230
570	0.170	0.270
569	0.140	0.210
568	0.120	0.170
567	0.140	0.160
566	0.080	0.140
565	0.000	0.050
564	-0.030	0.000
563	-0.030	-0.030
562	-0.050	-0.050
561	-0.060	-0.080
560	-0.040	-0.090
559	-0.050	-0.090
558	-0.040	-0.090
557	-0.040	-0.090
556	-0.020	-0.090
555	-0.020	-0.060
554	0.070	0.050
553	0.090	0.010
552	0.000	-0.020
551	0.020	-0.070
550	0.020	-0.060
549	0.020	-0.060
548	0.030	-0.020
	=====	=====
	0.084	0.101
	0.440	0.700

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LOCKPORT CONCRETE LOSS SURVEYS IN JUL 84 AND JAN 93
****

LAND WALL - BETWEEN POOLS
MONOLITH 44, 4' US OF DS JT

ELEV	LOSS 84 (FT)	LOSS 93 (FT)
578	0.170	0.240
577	0.460	0.580
576	0.350	0.440
575	0.340	0.380
574	0.280	0.330
573	0.200	0.200
572	0.210	0.210
571	0.150	0.140
570	0.100	0.120
569	0.050	0.080
568	0.040	0.000
567	0.040	-0.020
566	0.040	-0.020
565	0.050	-0.010
564	0.060	0.090
563	0.060	0.040
562	0.060	-0.030
561	0.060	-0.010
560	0.140	0.120
559	0.100	0.080
558	0.060	-0.050
557	0.050	0.000
556	0.050	-0.020
555	0.050	0.000
554	0.050	-0.070
553	0.140	0.080
552	0.120	0.080
551	0.130	-0.010
550	0.100	0.020
549	0.080	-0.020
548	0.080	-0.030
AVERAGE	0.125	0.095
MAX	0.460	0.580

LAND WALL - BETWEEN POOLS
MONOLITH 48, CENTERLINE

ELEV	LOSS 84 (FT)	LOSS 93 (FT)
578	0.460	0.450
577	0.800	0.890
576	0.500	0.600
575	0.360	0.480
574	0.260	0.490
573	0.220	0.340
572	0.270	0.430
571	0.260	0.330
570	0.270	0.290
569	0.190	0.280
568	0.200	0.300
567	0.220	0.280
566	0.170	0.160
565	0.260	0.280
564	0.260	0.230
563	0.330	0.270
562	0.270	0.280
561	0.220	0.230
560	0.210	0.240
559	0.200	0.200
558	0.110	0.150
557	0.280	0.200
556	0.310	0.210
555	0.160	0.150
554	0.170	0.100
553	0.110	0.090
552	0.110	0.070
551	0.090	-0.020
550	0.190	0.110
549	0.290	0.170
548	0.190	0.120
	0.256	0.271
	0.800	0.890

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LOCKPORT CONCRETE LOSS SURVEYS IN JUL 84 AND JAN 93
****

RIVER WALL - BETWEEN POOLS
MONOLITH 23, CENTERLINE

ELEV	LOSS 84 (FT)	LOSS 93 (FT)
578	0.160	0.260
577	0.300	0.400
576	0.210	0.320
575	0.230	0.290
574	0.110	0.230
573	0.120	0.150
572	0.130	0.160
571	0.110	0.150
570	0.140	0.160
569	0.250	0.250
568	0.250	0.330
567	0.150	0.190
566	0.070	0.100
565	0.050	0.060
564	0.040	0.090
563	0.070	0.150
562	0.060	0.150
561	0.070	0.040
560	0.050	0.040
559	0.020	0.010
558	0.030	0.020
557	0.010	-0.020
556	0.050	0.030
555	0.150	0.150
554	0.040	0.050
553	0.060	0.060
552	0.050	0.040
551	0.050	0.000
550	0.040	0.000
549	0.050	0.010
548	0.090	0.050
AVERAGE	0.104	0.126
MAX	0.300	0.400

RIVER WALL - BETWEEN POOLS
MONOLITH 39/41 JOINT

ELEV	LOSS 84 (FT)	LOSS 93 (FT)
578	0.160	0.210
577	0.360	0.430
576	0.290	0.340
575	0.200	0.240
574	0.230	0.230
573	0.160	0.180
572	0.180	0.250
571	0.190	0.230
570	0.170	0.170
569	0.160	0.190
568	0.160	0.180
567	0.200	0.240
566	0.230	0.280
565	0.170	0.200
564	0.170	0.190
563	0.180	0.200
562	0.140	0.160
561	0.170	0.130
560	0.160	0.110
559	0.170	0.110
558	0.200	0.140
557	0.160	0.090
556	0.170	0.150
555	0.270	0.320
554	0.120	0.100
553	0.130	0.080
552	0.140	0.080
551	0.170	0.100
550	0.160	0.100
549	0.170	0.090
548	0.170	0.130
	0.184	0.182
	0.360	0.430

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LOCKPORT CONCRETE LOSS SURVEYS IN JUL 84 AND JAN 93

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RIVER WALL - BETWEEN POOLS
MONOLITH 41 1' DS OF US JT

ELEV	LOSS 84 (FT)	LOSS 93 (FT)
578	0.160	0.250
577	0.320	0.420
576	0.270	0.320
575	0.220	0.320
574	0.140	0.220
573	0.060	0.180
572	0.020	0.140
571	0.030	0.100
570	0.150	0.120
569	0.010	0.040
568	0.000	0.060
567	0.030	0.130
566	0.180	0.200
565	0.120	0.140
564	-0.010	0.110
563	0.020	0.130
562	0.000	0.070
561	0.010	-0.020
560	0.000	0.060
559	0.020	0.000
558	0.000	0.050
557	0.020	0.020
556	0.020	0.080
555	0.030	0.080
554	0.020	0.010
553	0.020	0.000
552	0.040	0.010
551	0.020	0.000
550	0.040	0.010
549	0.040	0.010
548	0.050	0.010
	=====	=====
AVERAGE	0.066	0.105
MAX	0.320	0.420

RIVER WALL - BETWEEN POOLS
MONOLITH 41, CENTERLINE

ELEV	LOSS 84 (FT)	LOSS 93 (FT)
578	0.080	0.180
577	0.240	0.360
576	0.190	0.300
575	0.110	0.180
574	0.090	0.190
573	0.040	0.120
572	0.020	0.110
571	-0.010	0.110
570	0.020	0.060
569	-0.060	0.070
568	-0.050	0.000
567	-0.050	0.050
566	0.070	0.140
565	0.090	0.140
564	0.070	0.130
563	-0.010	0.090
562	-0.030	0.020
561	-0.040	0.010
560	-0.040	-0.040
559	-0.040	-0.030
558	-0.020	-0.030
557	-0.030	-0.020
556	-0.040	0.010
555	0.050	0.010
554	0.010	0.130
553	0.000	0.120
552	-0.010	0.040
551	-0.010	-0.010
550	0.000	0.000
549	0.000	0.010
548	0.000	0.010
	=====	=====
	0.021	0.079
	0.240	0.360

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LOCKPORT CONCRETE LOSS SURVEYS IN JUL 84 AND JAN 93

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RIVER WALL - BETWEEN POOLS
MONOLITH 47 1' DS OF US JT

ELEV	LOSS 84 (FT)	LOSS 93 (FT)
578	-0.010	0.010
577	-0.010	0.040
576	0.050	0.190
575	0.120	0.300
574	0.200	0.320
573	0.220	0.350
572	0.180	0.270
571	0.090	0.130
570	-0.020	0.010
569	-0.020	-0.010
568	-0.020	0.000
567	-0.030	-0.010
566	-0.030	-0.020
565	-0.030	-0.030
564	-0.020	-0.030
563	-0.020	-0.020
562	0.010	0.060
561	0.000	-0.020
560	0.030	0.100
559	0.060	0.110
558	0.010	0.090
557	0.000	0.050
556	0.000	0.060
555	0.010	0.030
554	0.030	0.100
553	0.040	0.130
552	0.040	0.130
551	0.050	0.100
550	0.010	0.080
549	0.010	0.050
548	0.010	0.020
AVERAGE	0.033	0.030
MAX	0.220	0.350

Appendix B
Field Logs for Point Marion Loss Measurements

Lock 8 Monongahela River

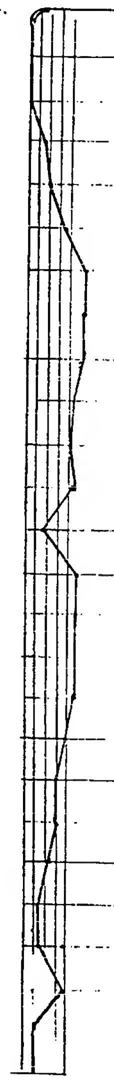
Land Wall Monolith-15 Station 1+63.11

Temp 64°

Upper Pool 793.2

Top of Wall 803.0

MJ-14¢15



Upper Pool EL 793.0

Lower Pool EL 778.0

0	1'
0	2'
5"	3'
6"	4'
10"	5'
15¼	6'
15"	7'
15"	8'
13"	9'
12"	10'
12½"	11
5"	12'
14½"	13'
14"	14'
14"	15'
14"	16'
12"	17'
9"	18'
9"	19'
7"	20'
4"	21'
4½"	22
11"	23
3"	24
3"	25

9/21/93

3/8 = 1'-0"

Lock 8 Monongahela River

Land Wall Monolith-15 Station 1+68 B

Temp 64°

Upper Pool 793.2

Top of Wall 803.0

Upper Pool EL 793.0

Lower Pool EL 778.0

1/2"	1'
1/2"	2'
1"	3'
1"	4'
1"	5'
1"	6'
1"	7'
2"	8'
3"	9'
3"	10'
7 1/2"	11
6"	12'
4 1/2"	13'
4"	14'
3"	15'
4"	16'
3"	17'
2"	18'
2 3/4"	19'
2 1/4"	20'
2 1/4"	21'
2 1/4"	22
2"	23
1 1/2"	24
2"	25

9/21/93

3/8 = 1'-0"

Lock 8 Monongahela River

Land Wall Monolith-15 Station 1+73 B

Temp 64°

Upper Pool 793.2

Top of Wall 803.0

0	1'
0	2'
1/2"	3'
1/2"	4'
3/4"	5'
1/2"	6'
0	7'
0	8'
1"	9'
4"	10'
8 3/4	11
5 1/2"	12'
5"	13'
4"	14'
4"	15'
4"	16'
3"	17'
1 1/2"	18'
2"	19'
2 1/2"	20'
1 1/4"	21'
1"	22
1 1/2"	23
2"	24
3"	25

Upper Pool EL 793.0

Lower Pool EL 778.0

9/21/93

3/8 = 1'-0"

Lock 8 Monongahela River

Land Wall Monolith-15 Station 1+78 B

Temp 64°

Upper Pool 793.2

Top of Wall 803.0

Upper Pool EL 793.0

Lower Pool EL 778.0

0	1'
0	2'
0	3'
0	4'
1/2"	5'
0	6'
0	7'
0	8'
1"	9'
3"	10'
9"	11
6 1/2"	12'
6"	13'
5"	14'
5 3/4"	15'
4"	16'
4"	17'
3 1/2"	18'
3 1/4"	19'
3"	20'
1 1/2"	21'
1 1/2"	22
1"	23
3"	24
3"	25

9/21/93

3/8 = 1'-0"

Lock 8 Monongahela River

Land Wall Monolith-15 Station 1+83 B

Temp 64°

Upper Pool 793.2

Top of Wall 803.0

Reading	Depth
0	1'
0	2'
0	3'
0	4'
1/4"	5'
0	6'
0	7'
0	8'
3/4"	9'
2"	10'
5"	11
9 1/4"	12'
7"	13'
4 1/2"	14'
4"	15'
4 3/4"	16'
3 1/2"	17'
2 1/2"	18'
3 3/4"	19'
4 1/2"	20'
6"	21'
5 1/2"	22
5"	23
5"	24
5"	25

Upper Pool EL 793.0

Lower Pool EL 778.0

9/21/93

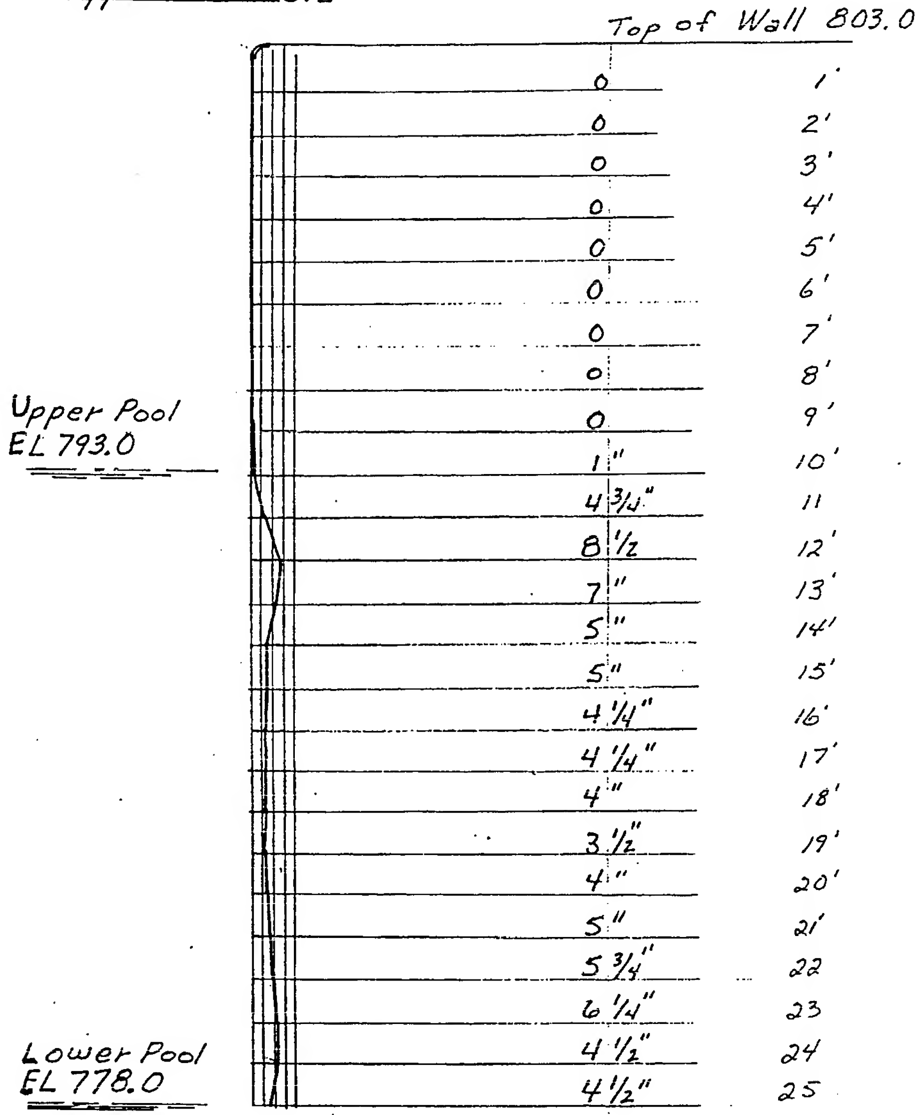
3/8 = 1'-0"

Lock 8 Monongahela River

Land Wall Monolith-15 Station 1+88 B

Temp 64°

Upper Pool 793.2



9/21/93

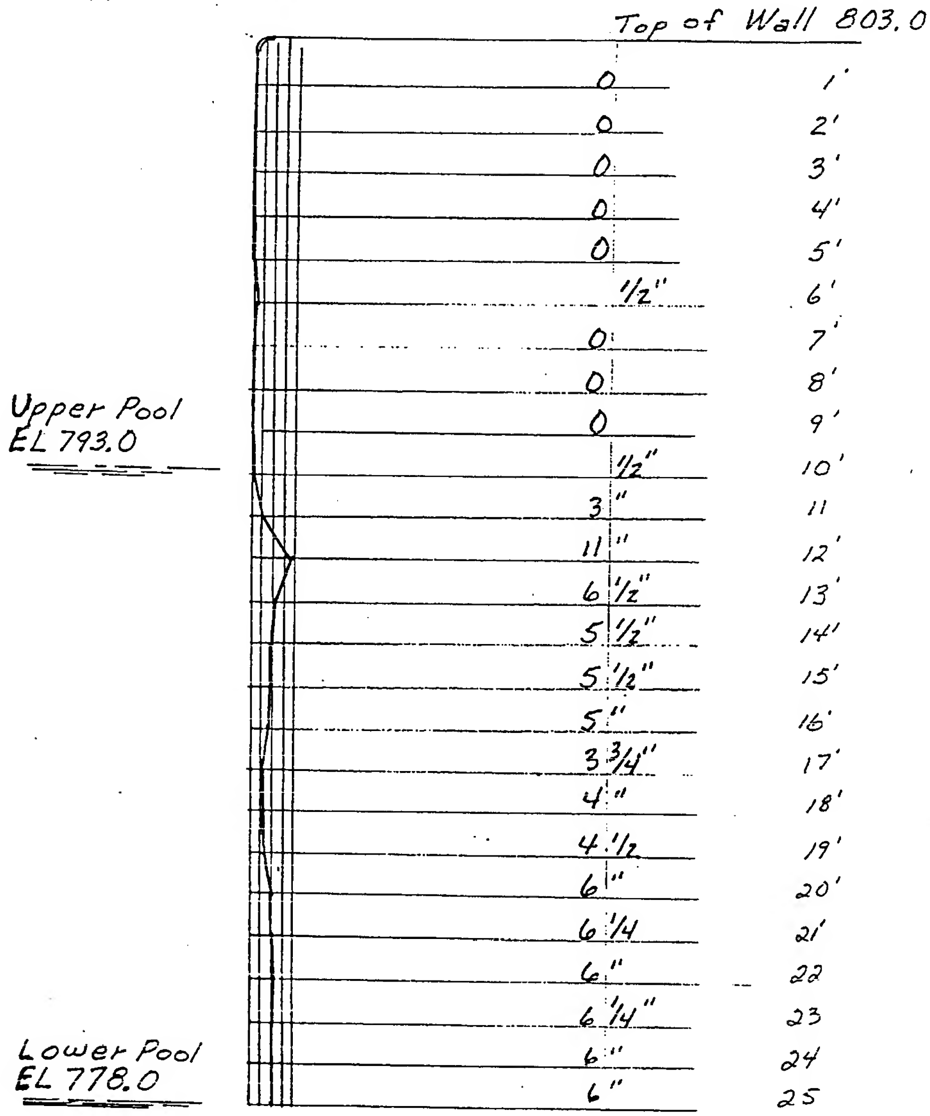
3/8 = 1'-0"

Lock 8 Monongahela River

Land Wall Monolith-15 Station 1+93B

Temp 64°

Upper Pool 793.2



9/21/93

3/8 = 1'-0"

Lock 8 Monongahela River

Land Wall Monolith-15 Station 1+98B

Temp 64°

Upper Pool 793.2

Top of Wall 803.0

0	1'
0	2'
0	3'
0	4'
0	5'
0	6'
0	7'
0	8'
0	9'
2"	10'
5"	11
8 1/2	12'
8"	13'
7"	14'
6"	15'
5"	16'
4 1/2"	17'
4 3/4"	18'
4"	19'
7"	20'
7"	21'
6 1/2"	22
5 1/2"	23
4 1/2"	24
4 1/2"	25

Upper Pool
EL 793.0

Lower Pool
EL 778.0

9/21/93

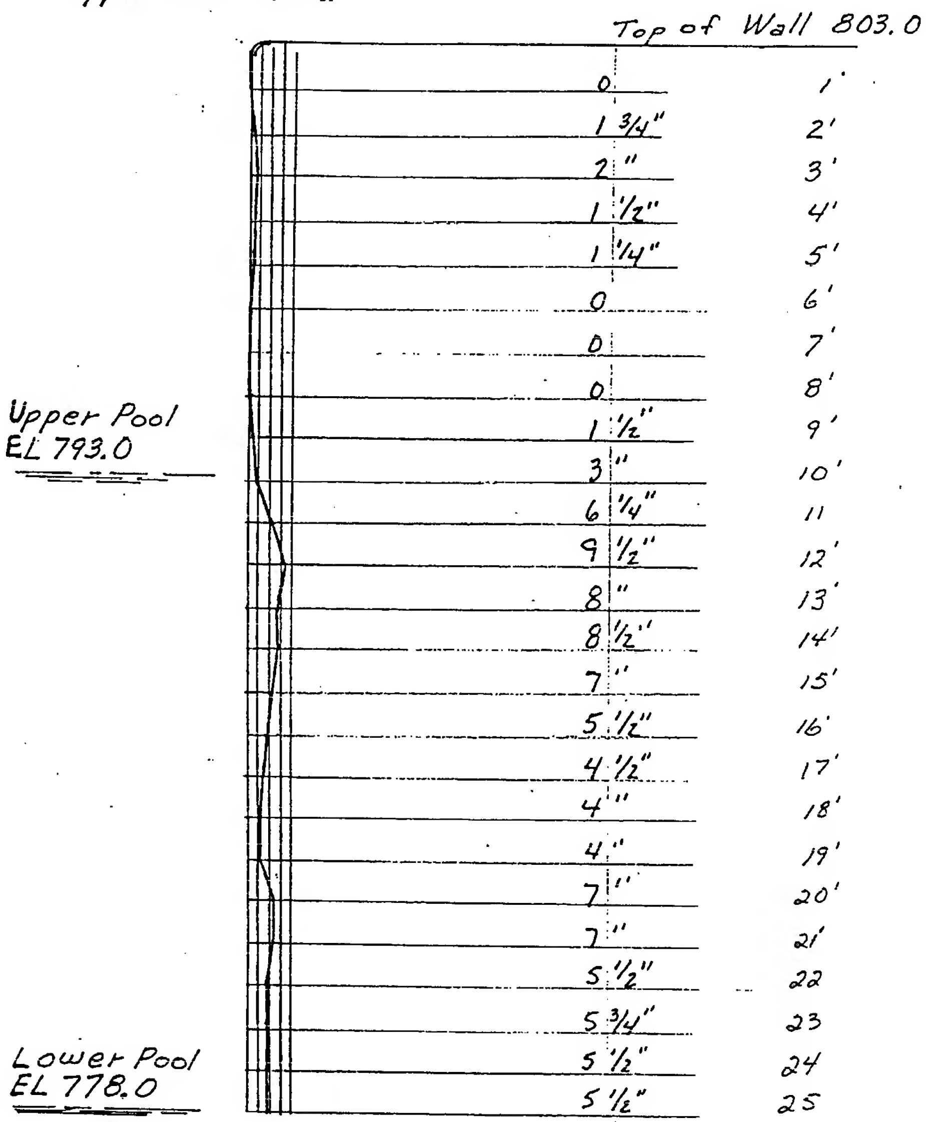
3/8 = 1'-0"

Lock 8 Monongahela River

Land Wall Monolith-15 Station 2+03 B

Temp 64°

Upper Pool 793.2



9/21/93

3/8 = 1'-0"

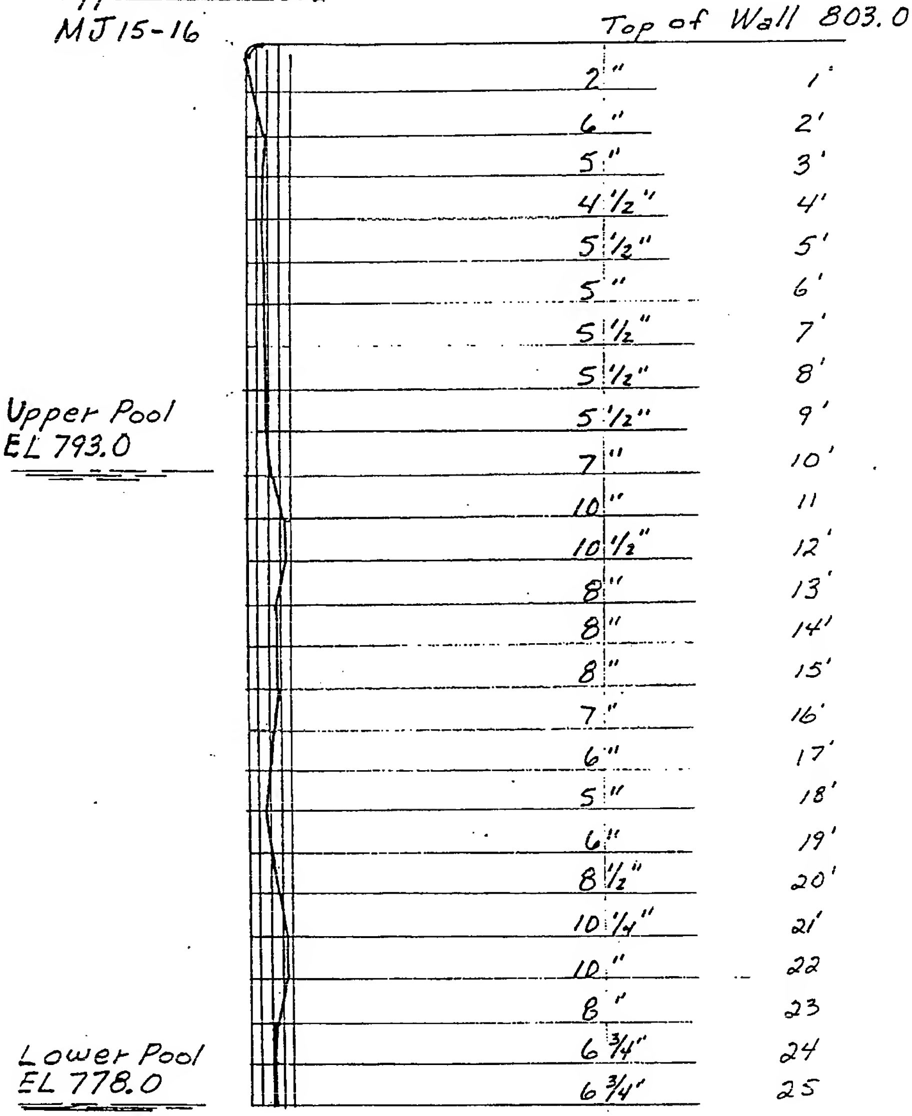
Lock 8 Monongahela River

Land Wall Monolith-15/16 Station 2+07

Temp 64°

Upper Pool 793.2

MJ15-16



9/21/93

3/8 = 1'-0"

Lock 8 - Monongahela River

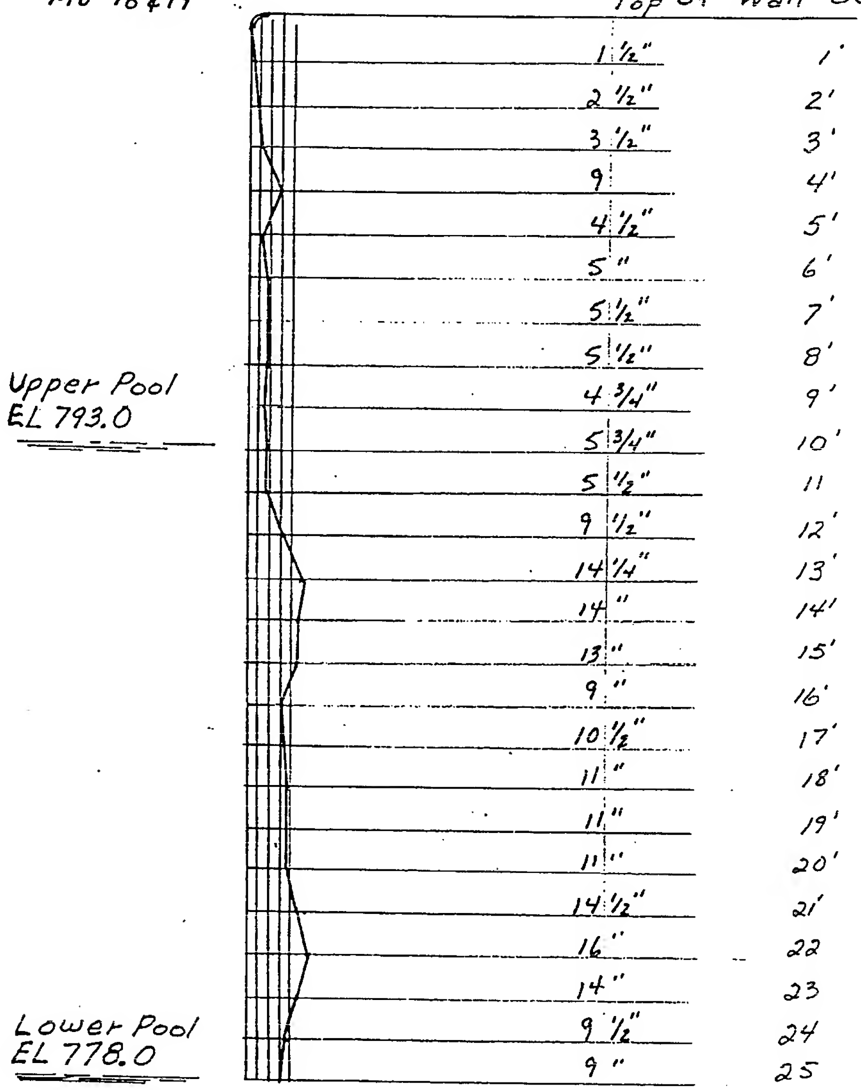
Land Wall Monolith - 19 Station 3+26 B

Temp 64°

Upper Pool 793.2

MJ 18 & 19

Top of Wall 803.0



9/21/93

3/8 = 1'-0"

Lock 8 Monongahela River

Land Wall Monolith-19 Station 3+31 E

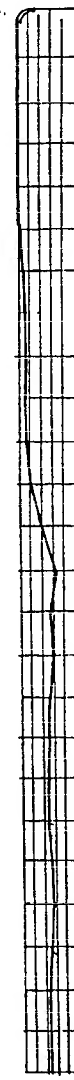
Temp 64°

Upper Pool 793.2

Top of Wall 803.0

Upper Pool EL 793.0

Lower Pool EL 778.0



Deflection	Depth
0	1'
0	2'
0	3'
0	4'
0	5'
1 1/2"	6'
2 1/2"	7'
2 1/2"	8'
2"	9'
2 1/2"	10'
3 1/2"	11
5"	12'
9 3/4"	13'
8 1/4"	14'
9"	15'
7 3/4"	16'
7 1/2"	17'
7"	18'
7"	19'
7 3/4"	20'
8"	21'
7 1/2"	22
6 3/4"	23
6 3/4"	24
6 3/4"	25

9/21/93

3/8" = 1'-0"

Lock 8 Monongahela River

Land Wall Monolith-19 Station 3+361

~~Temp 64°~~

~~Upper Pool~~ 793.2

Top of Wall 803.0

0	1'
0	2'
1"	3'
1"	4'
1"	5'
1 1/2"	6'
2"	7'
2"	8'
1 1/2"	9'
2"	10'
2 3/4"	11
4"	12'
1 1/2"	13'
8"	14'
8"	15'
7"	16'
6 3/4"	17'
6 1/2"	18'
6 1/2"	19'
7"	20'
8"	21'
7"	22
5 1/4"	23
5 1/4"	24
5 1/4"	25

Upper Pool
EL 793.0

Lower Pool
EL 778.0

9/21/93
3/8 = 1'-0"

Lock 8 Monongahela River

Land Wall Monolith-19 Station 3+41 B

Temp 64°

Upper Pool 793.2

Top of Wall 803.0

Upper Pool EL 793.0

Lower Pool EL 778.0

0	1'
0	2'
1"	3'
1 1/4"	4'
1 1/2"	5'
3"	6'
3"	7'
1	8'
1	9'
1	10'
1 1/2	11
0	12'
0	13'
0	14'
8"	15'
7 1/2"	16'
6 1/2"	17'
6"	18'
6"	19'
6"	20'
7"	21'
7"	22
6 1/2"	23
6 1/2	24
7"	25

9/21/93

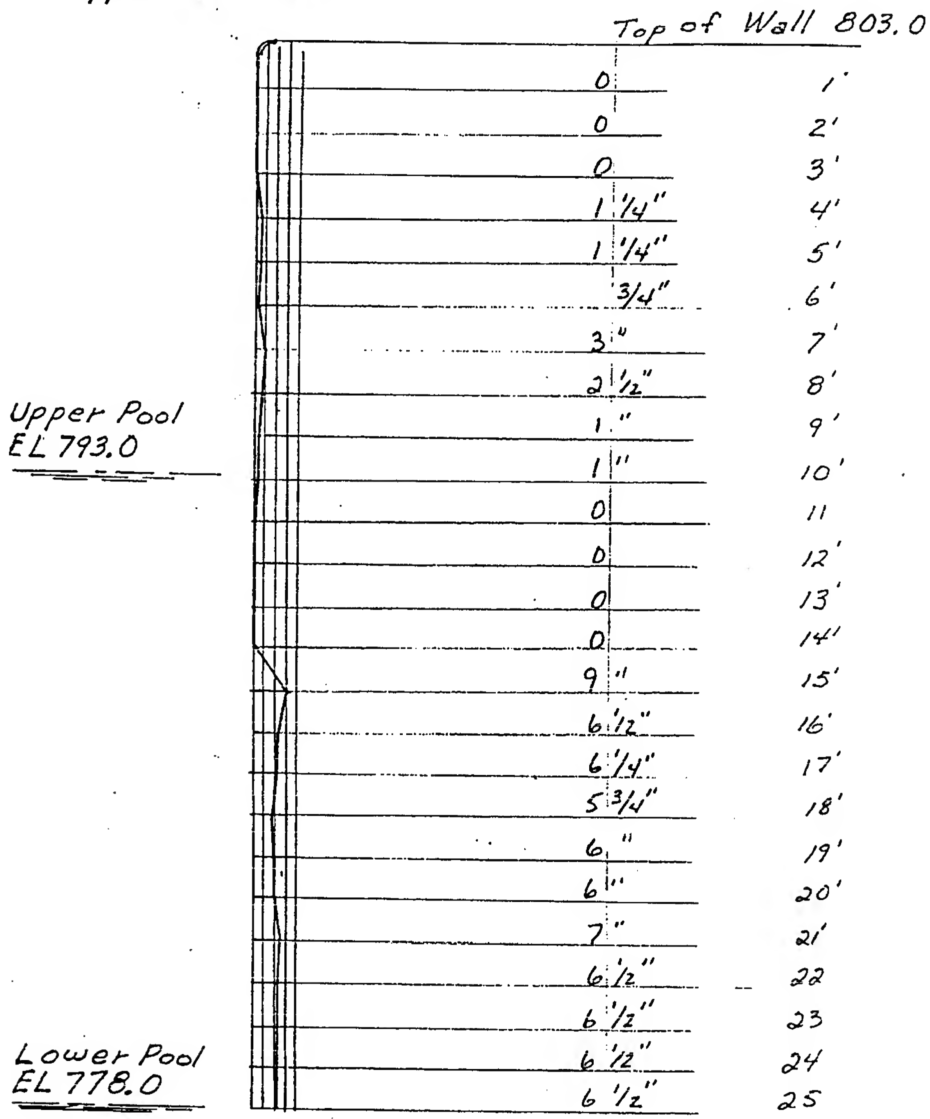
3/8 = 1'-0"

Lock 8 Monongahela River

Land Wall Monolith-19 Station 3+46±

Temp 64°

Upper Pool 793.2



9/21/93

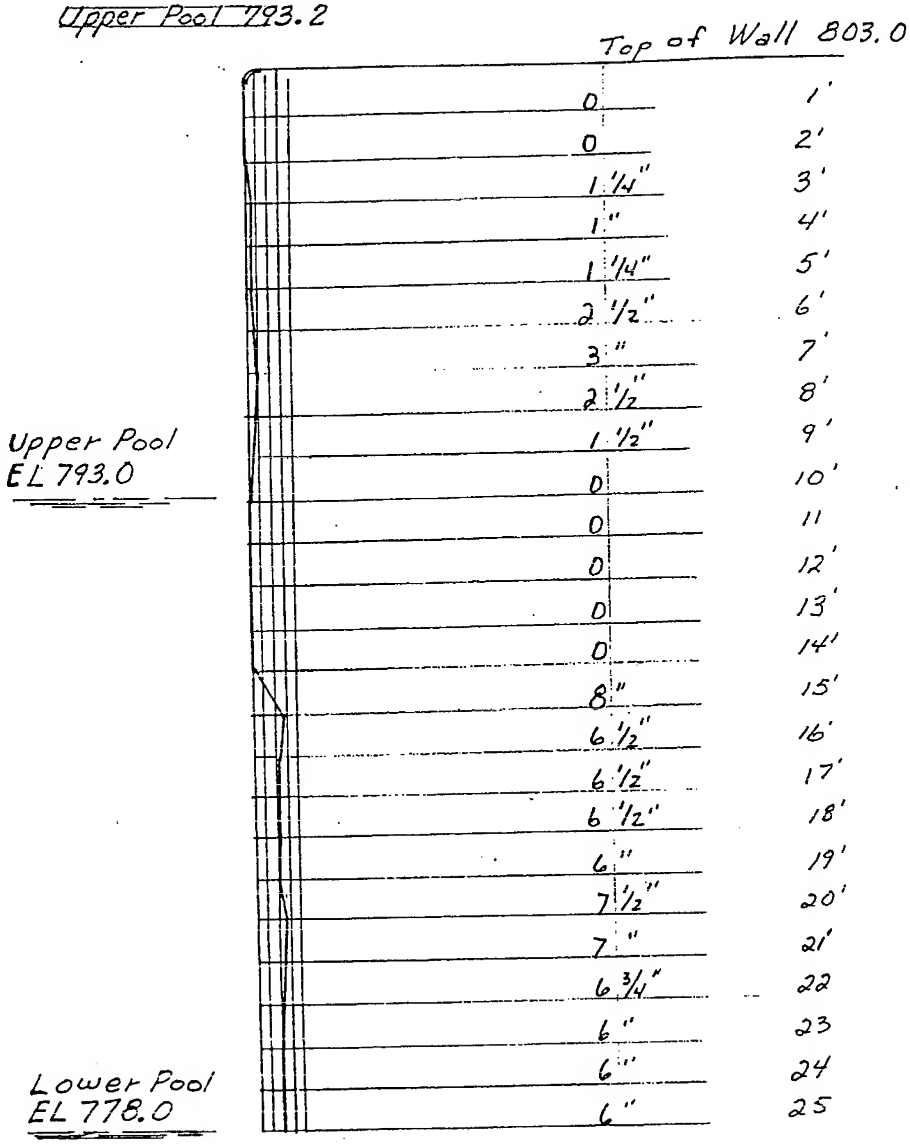
3/8" = 1'-0"

Lock 8 Monongahela River

Land Wall Monolith-19 Station 3+51

Temp 64°

Upper Pool 793.2



9/21/93

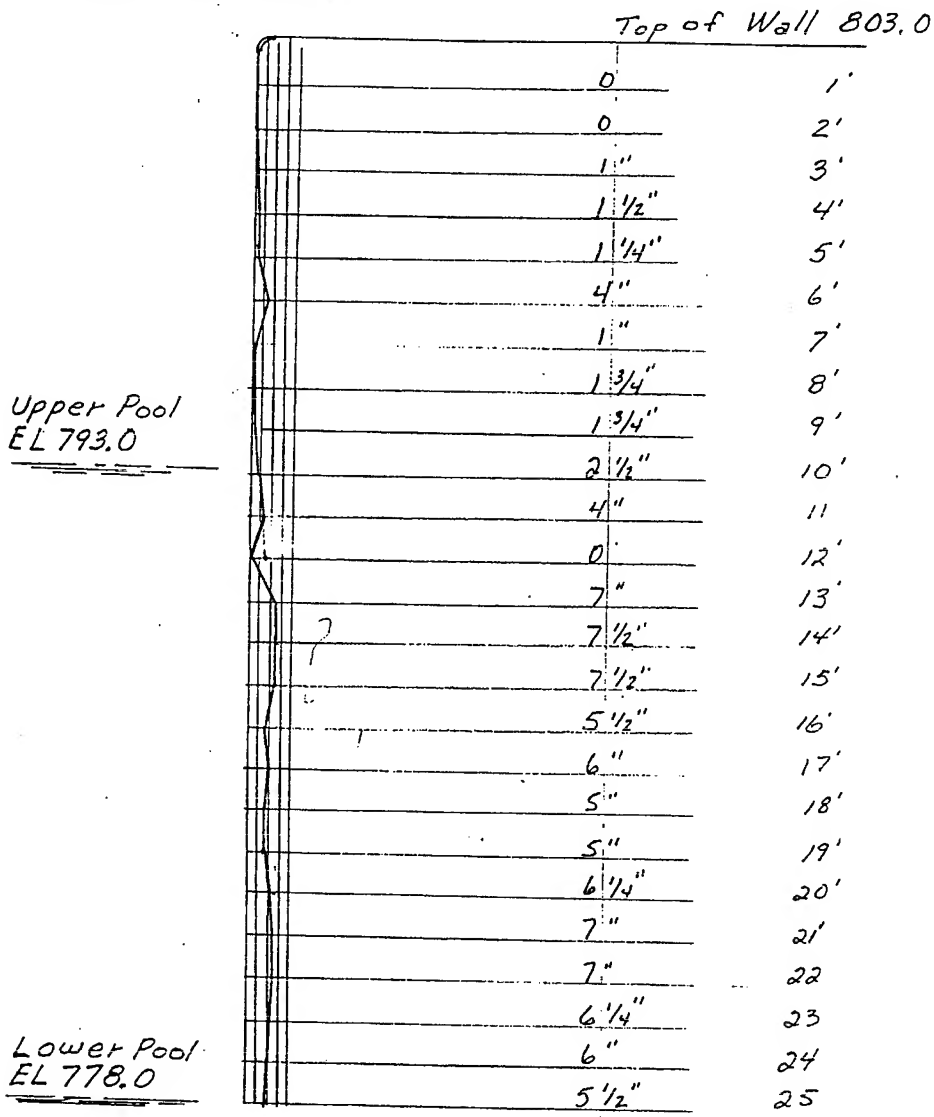
3/8=1'-0"

Lock 8 Monongahela River

Land Wall Monolith-19 Station 3+55

Temp 64°

Upper Pool 793.2



9/21/93

3/8 = 1'-0"

Lock 8 Monongahela River

Land Wall Monolith-19 Station 3+61 B

Temp 64°

Upper Pool 793.2

Top of Wall 803.0

Upper Pool
EL 793.0

Lower Pool
EL 778.0

0	1'
0	2'
0	3'
3/4"	4'
1 3/4"	5'
4"	6'
3 1/2"	7'
3"	8'
4 1/2"	9'
6"	10'
1"	11
1"	12'
2"	13'
5"	14'
8"	15'
7"	16'
8 1/2"	17'
6 1/2"	18'
6 1/4"	19'
7 1/2"	20'
7"	21'
6 1/4"	22
5 1/2"	23
5"	24
5 1/2"	25

9/21/93

3/8 = 1'-0"

Lock 8 Monongahela River

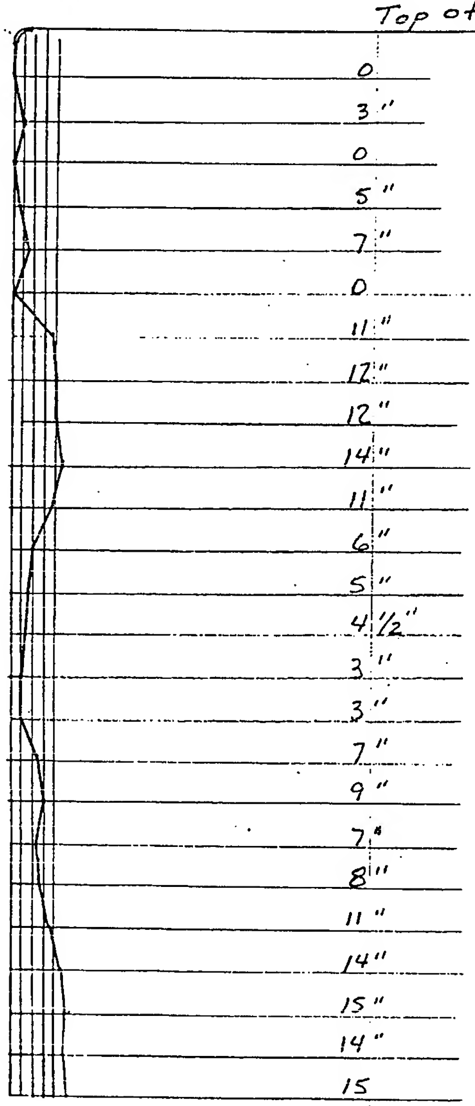
Land Wall Monolith- 19 & 20 Station 3+62 B

Temp 64°

Upper Pool 793.2

MJ 19 & 20

Top of Wall 803.0



0	1'
3"	2'
0	3'
5"	4'
7"	5'
0	6'
11"	7'
12"	8'
12"	9'
14"	10'
11"	11
6"	12'
5"	13'
4 1/2"	14'
3"	15'
3"	16'
7"	17'
9"	18'
7"	19'
8"	20'
11"	21'
14"	22
15"	23
14"	24
15	25

9/27/93

3/8 = 1'-0"

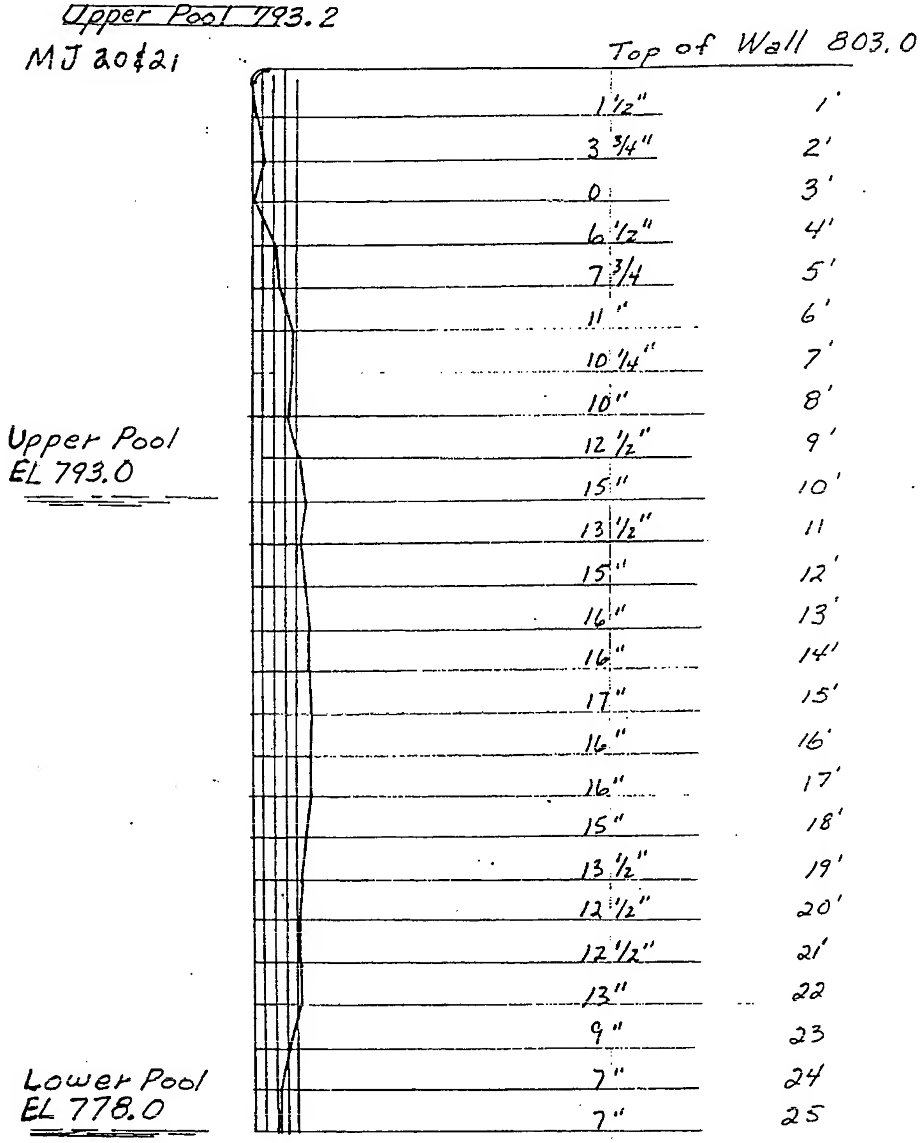
Lock 8 Monongahela River

Land Wall Monolith-20/21 Station 3+94B

Temp 64°

Upper Pool 793.2

MJ 20&21



9/27/93

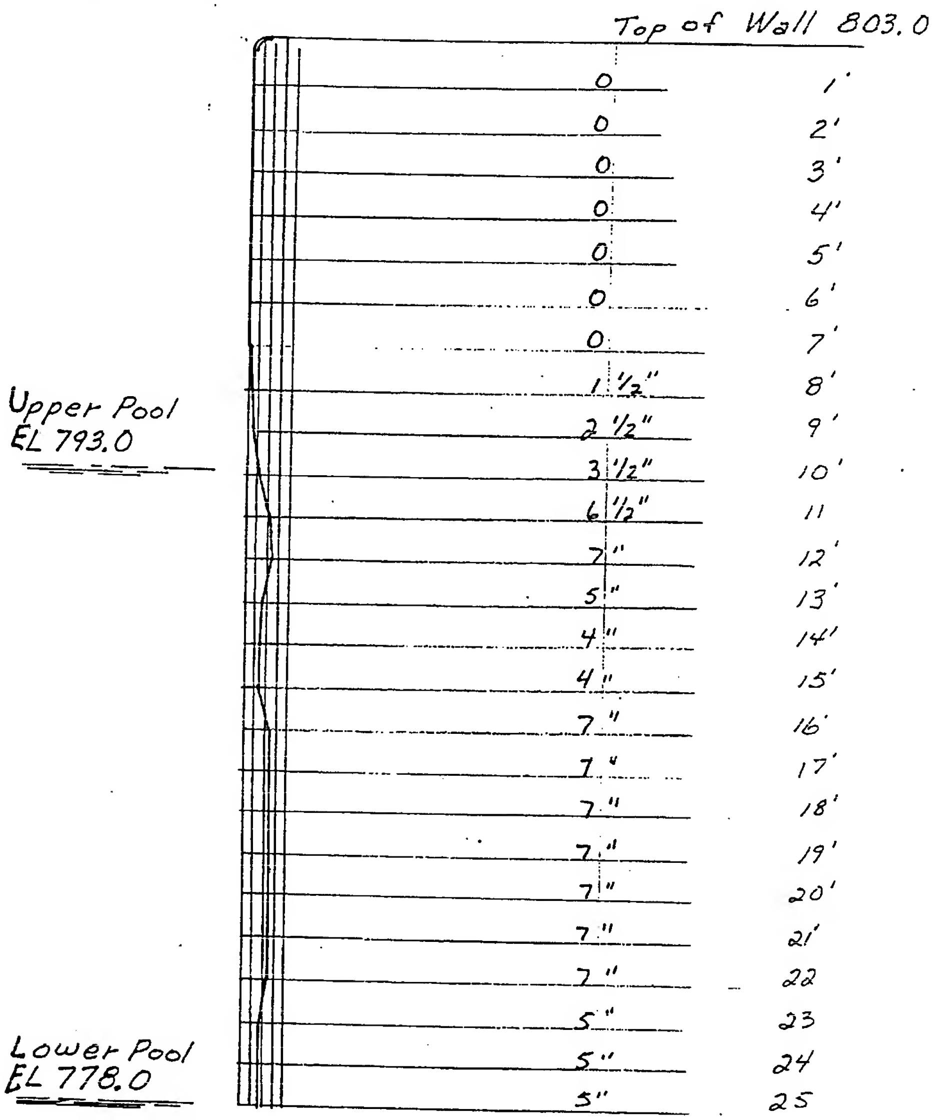
3/8 = 1'-0"

Lock 8 Monongahela River

Land Wall Monolith-21 Station 3+99

Temp 64°

Upper Pool 793.2



9/21/93

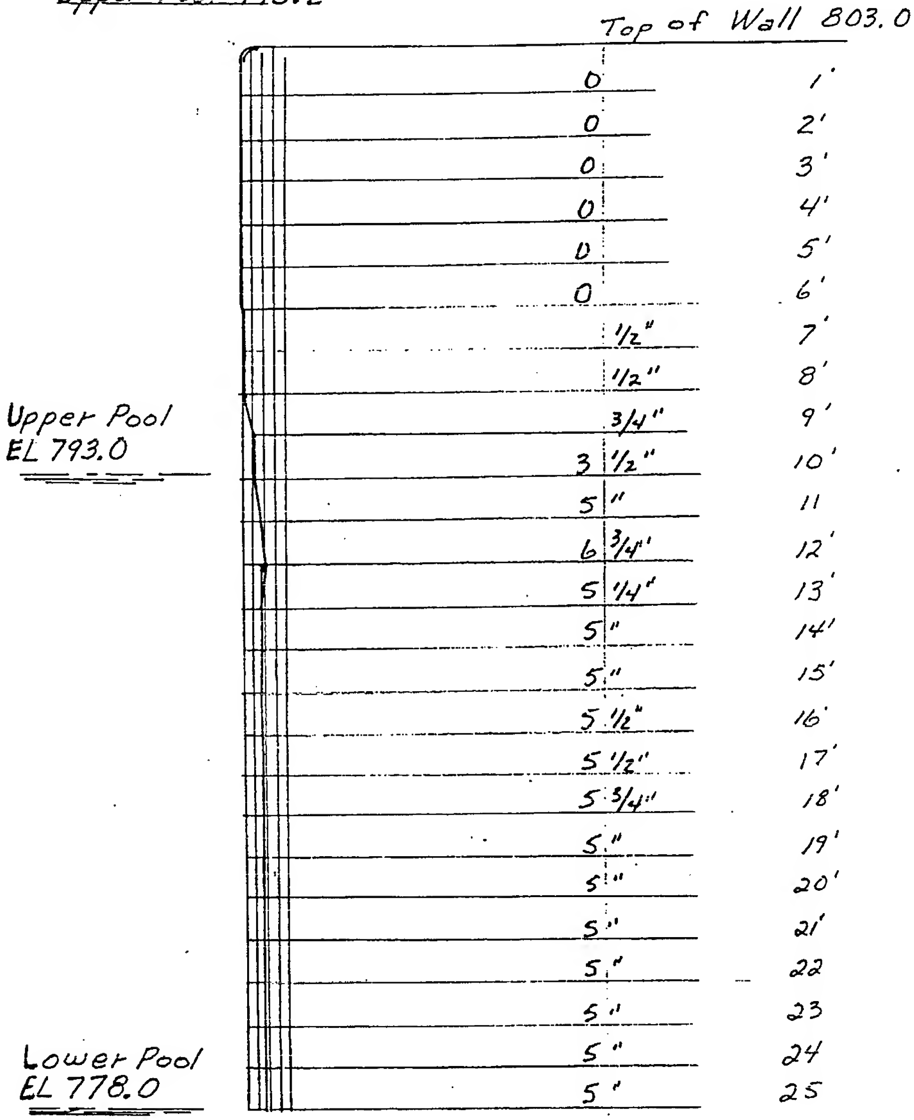
3/8 = 1'-0"

Lock 8 Monongahela River

Land Wall Monolith-21 Station 4+01

Temp 64°

Upper Pool 793.2



9/21/93

3/8 = 1'-0"

Lock 8 Monongahela River

Land Wall Monolith-21 Station 4+06

Temp 64°

Upper Pool 793.2

Top of Wall 803.0

0	1'
0	2'
0	3'
0	4'
0	5'
0	6'
1/2"	7'
1/2"	8'
1 1/2"	9'
1 1/2"	10'
4 1/2"	11
5 1/2"	12'
5"	13'
5"	14'
5"	15'
6"	16'
5"	17'
4 1/2"	18'
4 1/2"	19'
5"	20'
5"	21'
4 1/2"	22
4 1/2"	23
4 1/2"	24
4 1/2"	25

Upper Pool EL 793.0

Lower Pool EL 778.0

9/21/93

3/8 = 1'-0"

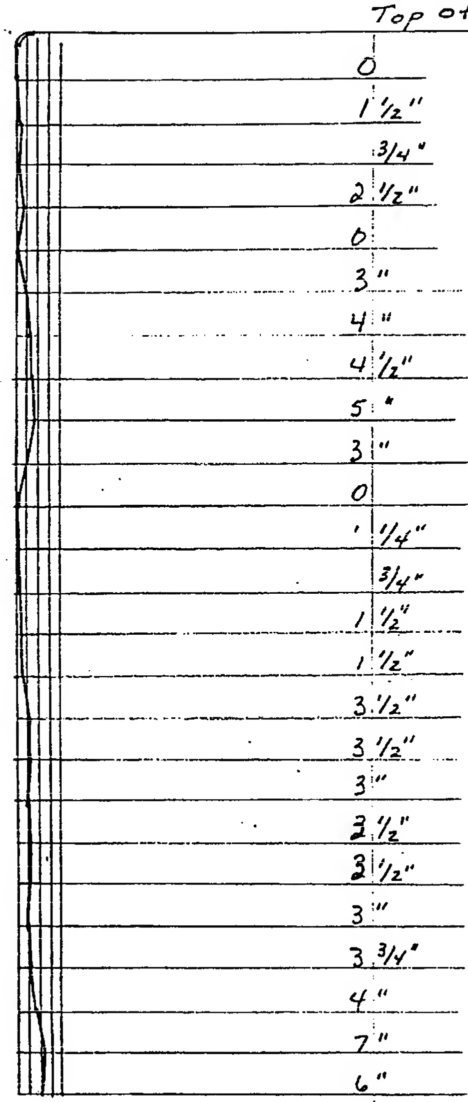
Lock 8 Monongahela River

Land Wall Monolith-21 Station 4+11

~~Temp 64°~~

~~Upper Pool 793.2~~

Top of Wall 803.0



Upper Pool EL 793.0

Lower Pool EL 778.0

Offset	Depth
0	1'
1 1/2"	2'
3/4"	3'
2 1/2"	4'
0	5'
3"	6'
4"	7'
4 1/2"	8'
5"	9'
3"	10'
0	11
1/4"	12'
3/4"	13'
1 1/2"	14'
1 1/2"	15'
3 1/2"	16'
3 1/2"	17'
3"	18'
3 1/2"	19'
3 1/2"	20'
3"	21'
3 3/4"	22
4"	23
7"	24
6"	25

9/21/93

3/8 = 1'-0"

Lock 8 Monongahela River

Land Wall Monolith-21 Station 4+16

Temp 64°

Upper Pool 793.2

Top of Wall 803.0

Upper Pool EL 793.0

Lower Pool EL 778.0

0	1'
0	2'
0	3'
0	4'
0	5'
0	6'
1/2"	7'
2"	8'
0	9'
0	10'
0	11
1 1/2"	12'
2"	13'
2"	14'
2"	15'
3"	16'
1 1/2"	17'
1 1/2"	18'
1 1/4"	19'
1 1/4"	20'
2"	21'
2 1/4"	22
2 1/2"	23
3"	24
3 1/2"	25

9/21/93

3/8 = 1'-0"

Lock 8 Monongahela River

Land Wall Monolith-21 Station 4+21 B

Temp 64°

Upper Pool 793.2

Top of Wall 803.0

Measurement	Depth
0	1'
0	2'
0	3'
0	4'
0	5'
0	6'
0	7'
2"	8'
1 1/4"	9'
2 1/4"	10'
4"	11
4 1/2"	12'
4 1/2"	13'
4 1/2"	14'
4 1/2"	15'
5"	16'
5"	17'
5"	18'
5"	19'
4"	20'
5"	21'
4 1/2"	22
3 3/4"	23
3 1/2"	24
3 1/2"	25

Upper Pool EL 793.0 (between 9' and 10')

Lower Pool EL 778.0 (between 24 and 25)

9/21/93

3/8 = 1'-0"

Lock 8 Monongahela River

River Wall Monolith-4/5 Station 0+81B

Temp 64°

Upper Pool 793.2

MJ 4&5

Top of Wall 803.0

Reading	Depth
0	1'
3/4"	2'
1"	3'
1"	4'
0"	5'
2"	6'
2"	7'
2"	8'
1"	9'
1"	10'
1 1/2	11
1 1/4"	12'
1 1/2"	13'
2"	14'
2"	15'
0	16'
0	17'
0	18'
0	19'
0	20'
0	21'
0	22
2"	23
0	24
0	25

Upper Pool EL 793.0

Lower Pool EL 778.0

9/27/93

3/8 = 1'-0"

Lock 8 Monongahela River

River Wall Monolith-5 Station 0+86 B

Temp 64°

Upper Pool 793.2

Top of Wall 803.0

	0	1'
	2"	2'
	2 1/4"	3'
	2"	4'
	1 1/2"	5'
	1"	6'
	1"	7'
	1 1/2"	8'
Upper Pool EL 793.0	1 1/2"	9'
	1 1/2"	10'
	1 1/4"	11
	1"	12'
	1"	13'
	0	14'
	0	15'
	0	16'
	1"	17'
	0	18'
	0	19'
	0	20'
	0	21'
	0	22
	0	23
Lower Pool EL 778.0	1"	24
	0	25

9/21/93

3/8 = 1'-0"

Lock 8 Monongahela River

River Wall Monolith-5 Station 0+918

Temp 64°

Upper Pool 793.2

Top of Wall 803.0

Upper Pool EL 793.0

Lower Pool EL 778.0

0	1'
2 3/4"	2'
3"	3'
3"	4'
2"	5'
2"	6'
2"	7'
3 1/2"	8'
4"	9'
6 1/2"	10'
5"	11
5 1/2"	12'
5 3/4"	13'
7"	14'
2 1/2"	15'
2"	16'
1 1/2"	17'
1 1/2"	18'
0	19'
0	20'
1 1/2"	21'
0	22
1	23
0	24
0	25

9/27/93

3/8 = 1'-0"

Lock 8 Monongahela River

River Wall Monolith-5 Station 0+96

~~Temp 64°~~
~~Upper Pool 793.2~~

Top of Wall 803.0

0	1'
1 1/2"	2'
1 1/2"	3'
2"	4'
1"	5'
1"	6'
1 3/4"	7'
1 3/4	8'
2 1/2"	9'
2 3/4"	10'
2 "	11
3 1/4"	12'
4"	13'
5"	14'
2"	15'
1/2"	16'
1/2"	17'
1/2"	18'
0	19'
1/2"	20'
0	21'
1	22
0	23
0	24
0	25

Upper Pool
EL 793.0

Lower Pool
EL 778.0

9/21/93
3/8 = 1'-0"

Lock 8 Monongahela River

River Wall Monolith-5 Station 1+01

Temp 64°

Upper Pool 793.2

Top of Wall 803.0

Upper Pool EL 793.0

Lower Pool EL 778.0

0	1'
1"	2'
1"	3'
1"	4'
1"	5'
1"	6'
1"	7'
1"	8'
1"	9'
1½"	10'
2"	11
2½"	12'
1"	13'
1"	14'
0	15'
1"	16'
2"	17'
1¼"	18'
1"	19'
1"	20'
1"	21'
1"	22
1"	23
0	24
0	25

9/21/93

3/8 = 1'-0"

Lock 8 Monongahela River
River Wall Monolith-5 Station 1+06

Temp 64°
Upper Pool 793.2

Top of Wall 803.0

0	1'
0	2'
1/2"	3'
1/2"	4'
0	5'
0	6'
0	7'
1"	8'
1 1/2"	9'
1 1/2"	10'
2"	11
2 1/2"	12'
0	13'
0	14'
0	15'
1/4"	16'
1/4"	17'
1/2"	18'
1"	19'
3/4"	20'
1/2"	21'
1/2"	22
2 1/4"	23
0	24
0	25

Upper Pool
EL 793.0

Lower Pool
EL 778.0

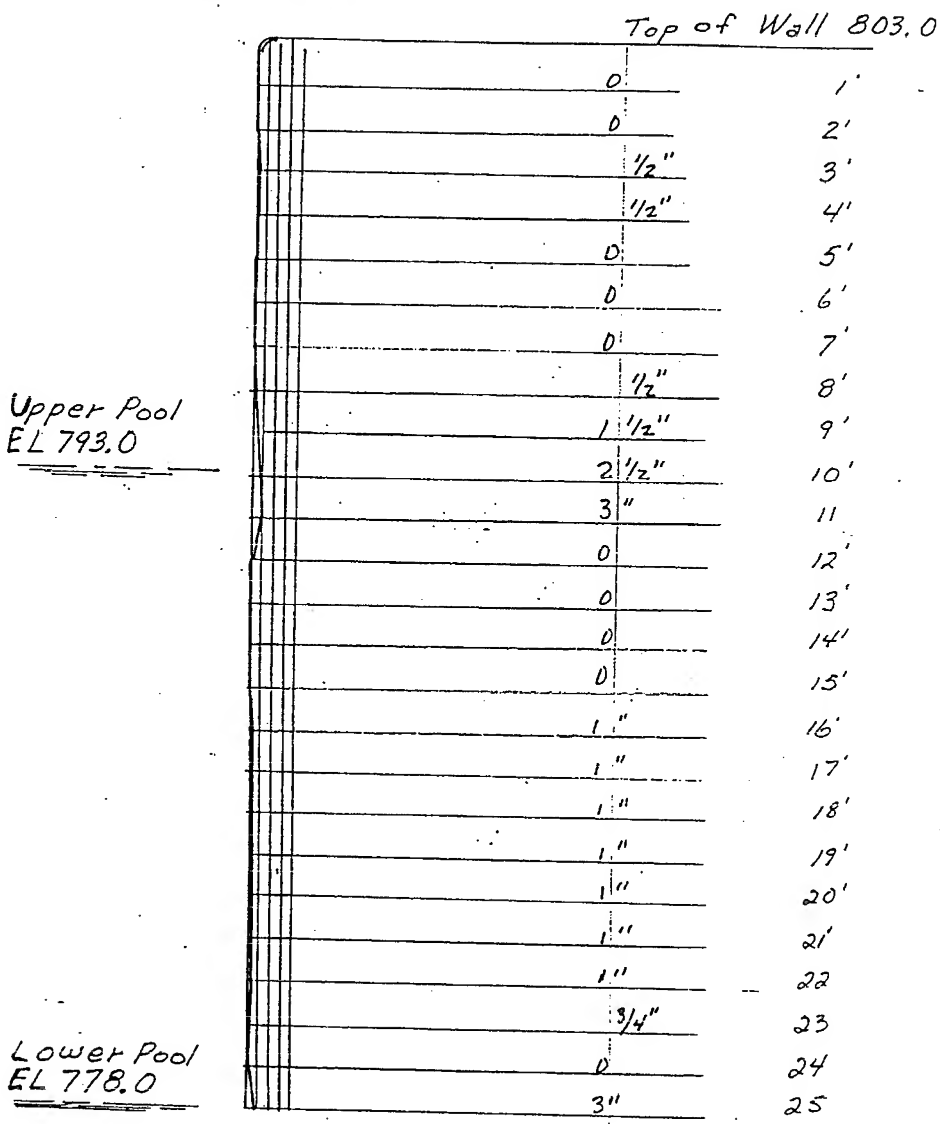
9/21/93
3/8 = 1'-0"

Lock 8 Monongahela River

River Wall Monolith-5 Station 1+11 B

Temp 64°

Upper Pool 793.2



9/21/93

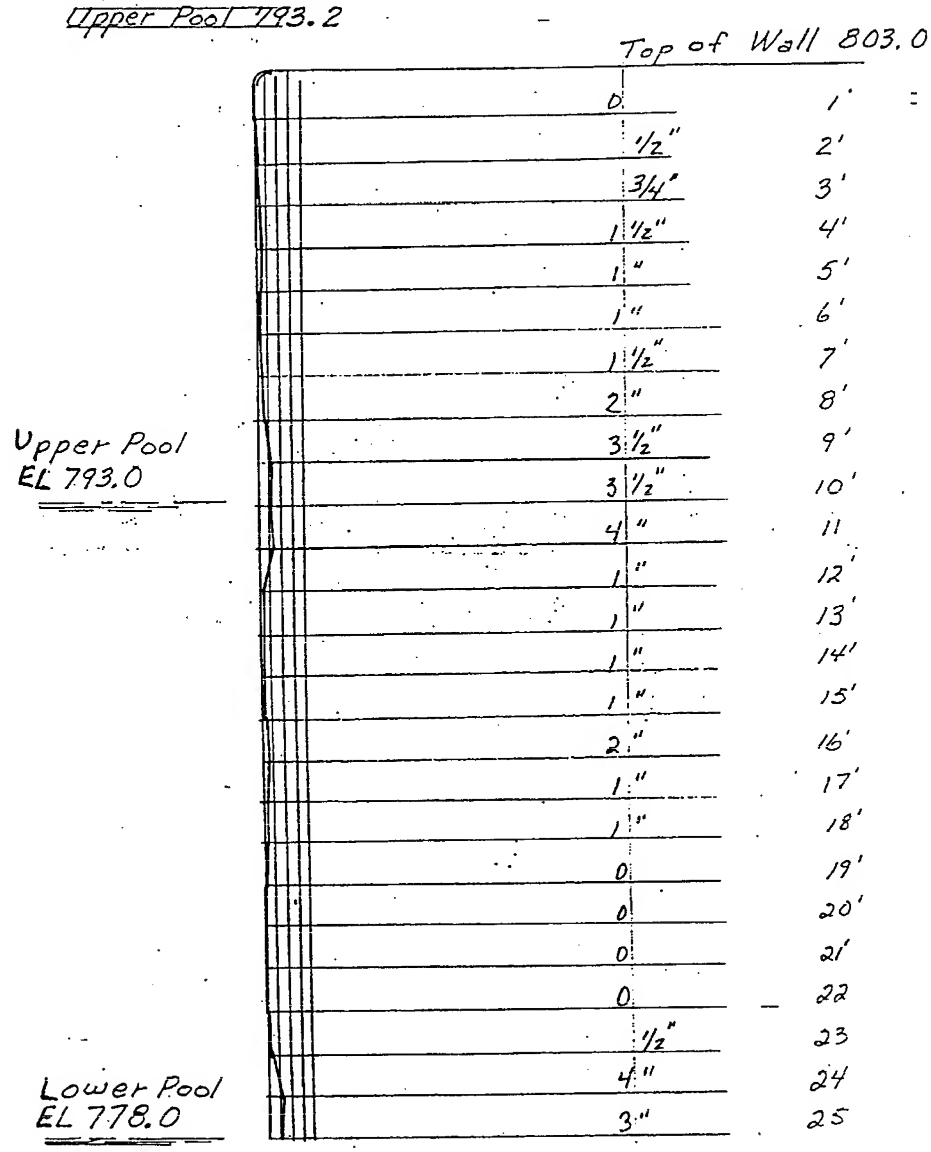
3/8 = 1'-0"

Lock 8 Monongahela River

River Wall Monolith-5 Station 1+16

Temp 64°

Upper Pool 793.2



9/21/93

3/8" = 1'-0"

Lock 8 Monongahela River

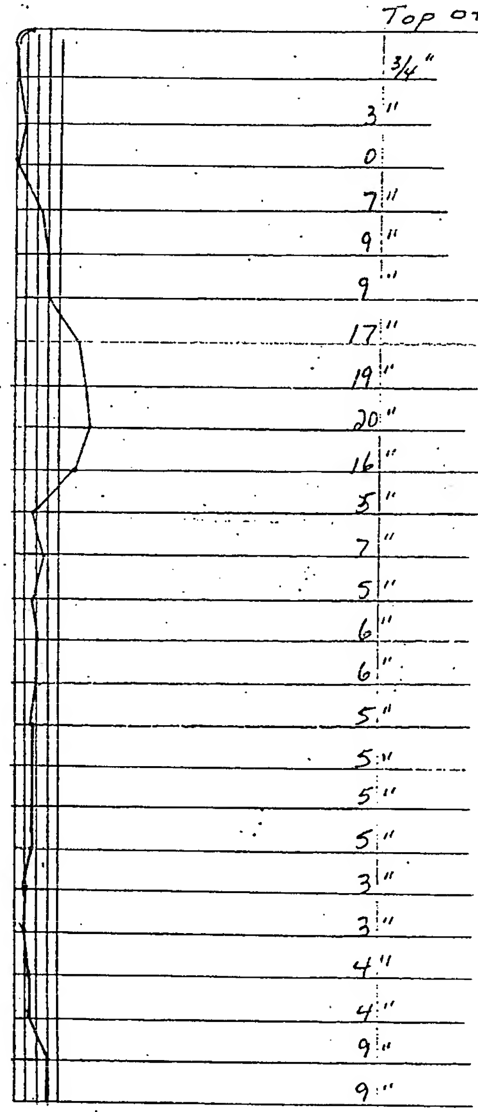
River Wall Monolith-5/6 Station 1+19.11B

Temp 64°

Upper Pool 793.2

MJ 5&6

Top of Wall 803.0



3/4"	1'
3"	2'
0	3'
7"	4'
9"	5'
9"	6'
17"	7'
19"	8'
20"	9'
16"	10'
5"	11
7"	12'
5"	13'
6"	14'
6"	15'
5"	16'
5"	17'
5"	18'
5"	19'
3"	20'
3"	21'
4"	22
4"	23
9"	24
9"	25

Upper Pool
EL 793.0

Lower Pool
EL 778.0

9/21/93
3/8 = 1'-0"

Lock 8 Monongahela River

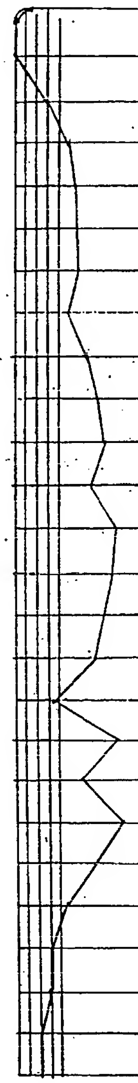
River Wall Monolith-11/12 Station 3+26B

Temp 64°

Upper Pool 793.2

MJ 11 & 12

Top of Wall 803.0



0	1'
9"	2'
14 1/4"	3'
16 1/2	4'
17"	5'
17"	6'
14"	7'
20"	8'
25 1/2"	9'
25	10'
20 1/2"	11
21"	12'
28 1/2"	13'
27"	14'
23"	15'
10"	16'
30	17'
19"	18'
30"	19'
23"	20'
13 1/2"	21'
9"	22
9"	23
6"	24
6"	25

9/21/93

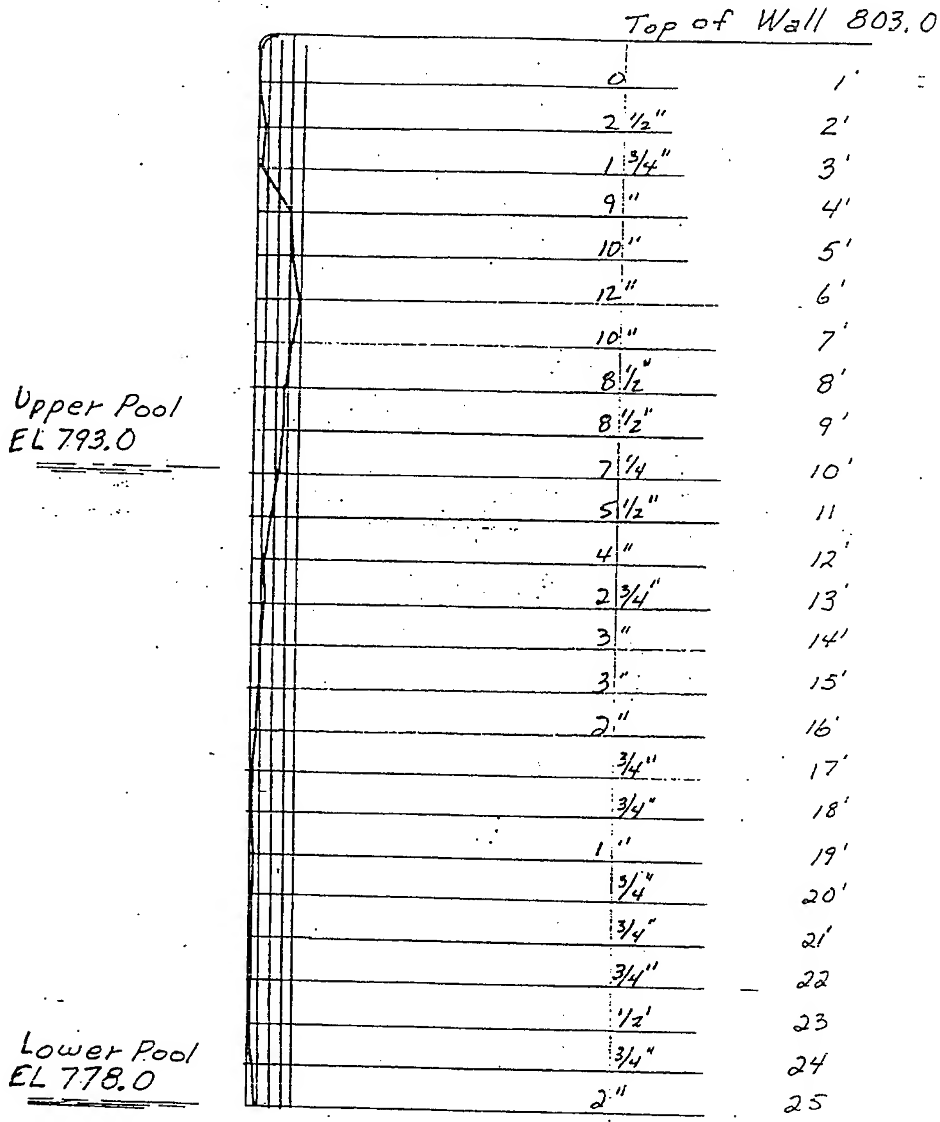
3/8 = 1'-0"

Lock 8 Monongahela River

River Wall Monolith-11 Station 3+31B

Temp 64°

Upper Pool 793.2



9/21/93

3/8 = 1'-0"

Lock 8 Monongahela River

River Wall Monolith - 11 Station 3+36

Temp 64°

Upper Pool 793.2

Top of Wall 803.0

Upper Pool EL 793.0

Lower Pool EL 778.0

0	1'
0	2'
1"	3'
1 1/2"	4'
0	5'
4"	6'
3"	7'
3"	8'
2 1/2"	9'
2 1/2"	10'
2 1/2"	11
3	12'
1 1/2"	13'
2"	14'
2"	15'
1"	16'
1"	17'
4"	18'
3 3/4"	19'
3 1/2"	20'
1"	21'
3/4"	22
1	23
2 1/2	24
3 1/2	25

9/21/93

3/8" = 1'-0"

Lock 8 Monongahela River

River Wall Monolith-11 Station 3+41B

Temp 64°

Upper Pool 793.2

Top of Wall 803.0

0	1'
0	2'
1/2"	3'
1 1/4"	4'
2"	5'
3"	6'
3"	7'
3"	8'
3"	9'
3 1/2"	10'
2 1/2"	11
1 3/4"	12'
2"	13'
2"	14'
3"	15'
1"	16'
1"	17'
1 1/2"	18'
3 1/2"	19'
3"	20'
1 1/2"	21'
1 1/2"	22
1"	23
2 1/2"	24
3"	25

Upper Pool EL 793.0

Lower Pool EL 778.0

9/21/93

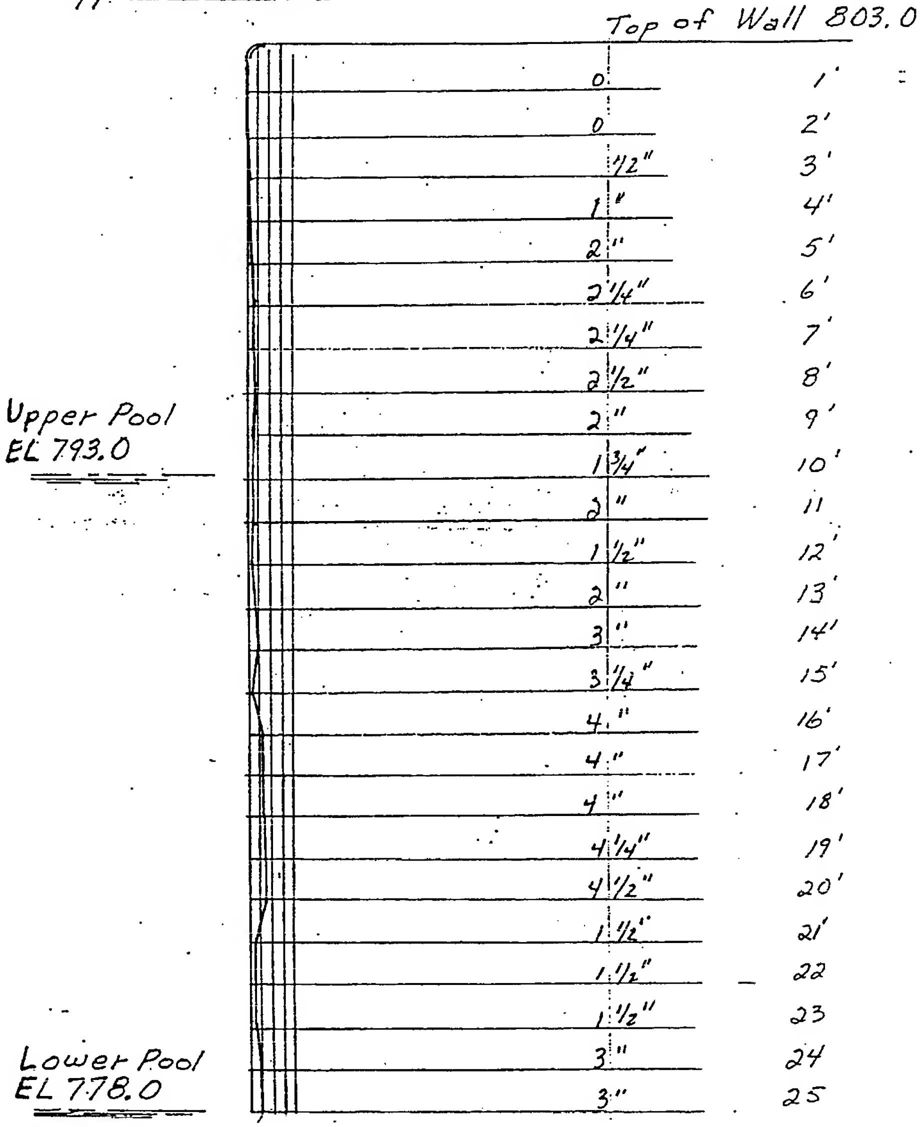
3/8 = 1'-0"

Lock 8 Monongahela River

River Wall Monolith-11 Station 3+46B

Temp 64°

Upper Pool 793.2



9/21/93

3/8 = 1'-0"

Lock 8 Monongahela River

River Wall Monolith-11 Station 3+51

Temp 64°

Upper Pool 793.2

Top of Wall 803.0

Reading	Depth
0	1'
0	2'
0	3'
0	4'
0	5'
0	6'
0	7'
2 1/2"	8'
2 1/2"	9'
2 3/4"	10'
2 3/4"	11
2"	12'
2"	13'
1 1/2"	14'
3"	15'
1"	16'
1"	17'
2"	18'
3"	19'
3 1/2"	20'
1 1/2"	21'
1 1/4"	22
1 1/2"	23
2 1/2"	24
3"	25

Upper Pool EL 793.0

Lower Pool EL 778.0

9/21/93

3/8 = 1'-0"

Lock 8 Monongahela River

River Wall Monolith-11 Station 3+56B

Temp 64°

Upper Pool 793.2

Top of Wall 803.0

0	1'
0	2'
3/4"	3'
3/4"	4'
0	5'
0	6'
2"	7'
2"	8'
2 1/2"	9'
2 1/2"	10'
2 1/2"	11
2 1/2"	12'
2"	13'
2"	14'
1"	15'
1"	16'
3 1/4"	17'
3 1/2"	18'
3 3/4"	19'
3"	20'
1 1/2"	21'
1 3/4"	22
1 1/2	23
5"	24
3"	25

Upper Pool EL 793.0

Lower Pool EL 778.0

9/21/93

3/8 = 1'-0"

Lock 8 Monongahela River

River Wall Monolith-11 Station 3+61B

Temp 64°

Upper Pool 793.2

Top of Wall 803.0

Upper Pool EL 793.0

Lower Pool EL 778.0

0	1'
0	2'
3/4"	3'
1/4"	4'
0	5'
0	6'
0	7'
2"	8'
3"	9'
3 1/2"	10'
4 1/2"	11
4 1/2	12'
5 "	13'
3"	14'
3"	15'
1 1/2"	16'
1 1/2"	17'
3"	18'
4"	19'
2"	20'
2"	21'
2 1/4"	22
2"	23
6"	24
3"	25

9/21/93

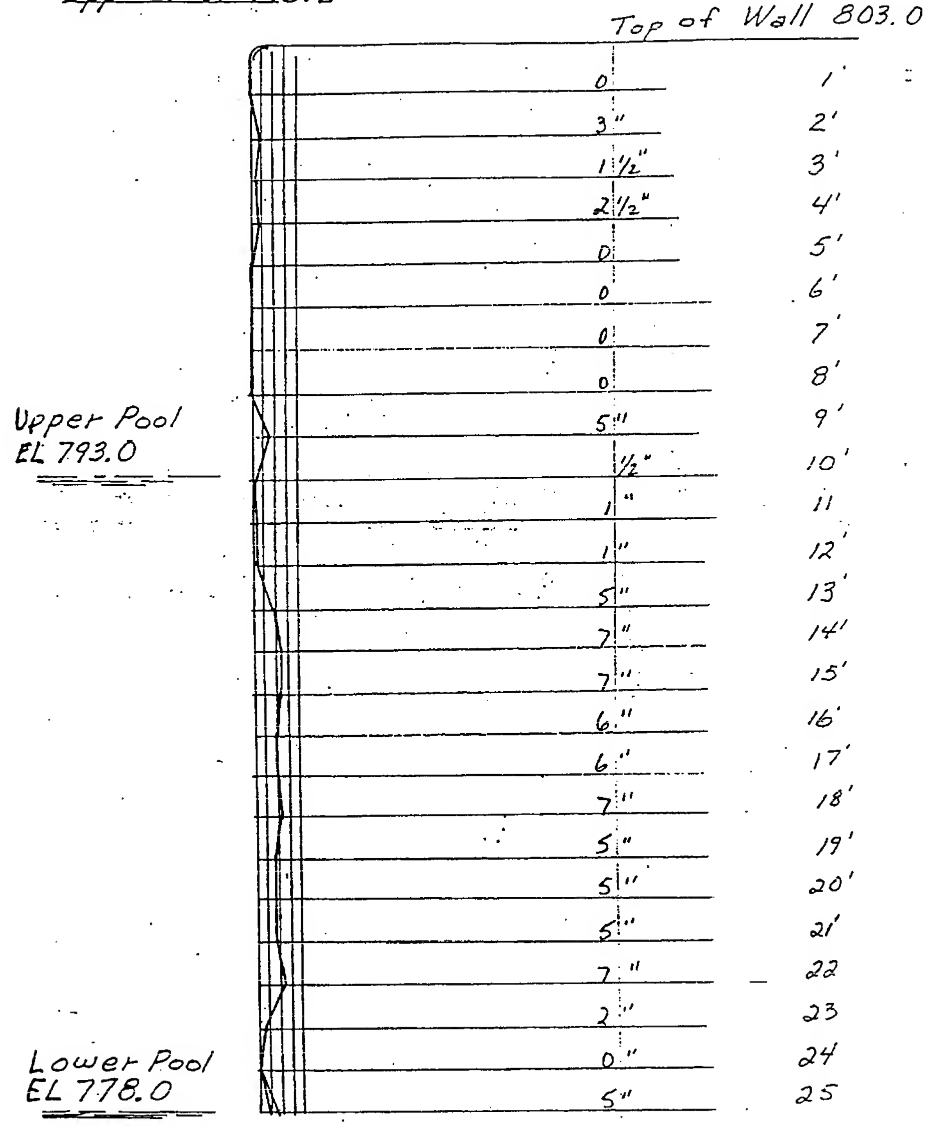
3/8 = 1'-0"

Lock 8 Monongahela River

River Wall Monolith-11/12 Station 3+62B

Temp 64

Upper Pool 793.2



9/21/93

3/8 = 1'-0"

Appendix C
Field Logs for Lock and Dam 13 Loss Measurements

Lock 13

Land wall
Monolith 41 - 1 ft from U/S joint

Top of lock wall elevation	592.0
Upper pool	583.0
Lower pool	572.0
Gage zero	568.7
Stage upper pool	14.46
Stage lower pool	6.75

Depth (feet)	Loss (feet)
1	0.03
2	0.06
3	0.02
4	0.01
5	0
6	0.02
7	0.01
8	0.01
9	0.03
10	0.02
11	0.04
12	0.07
13	0.03
14	0.02
15	0.06
16	0.11

Lock 13

Land wall
Monolith 42 - 8.5 ft from D/S joint

Top of lock wall elevation	592.0
Upper pool	583.0
Lower pool	572.0
Gage zero	568.7
Stage upper pool	14.46
Stage lower pool	6.75

Depth (feet)	**Loss** (feet)
1	0.01
2	0.02
3	0.02
4	0.01
5	0
6	0.01
7	0.05
8	0.04
9	0.01
10	0
11	0.02
12	0.01
13	0.02
14	0
15	0.01
16	0

Lock 13

Land wall
Monolith 38 - 7 ft from U/S joint

Top of lock wall elevation	592.0
Upper pool	583.0
Lower pool	572.0
Gage zero	568.7
Stage upper pool	14.46
Stage lower pool	6.75

Depth (feet)	**Loss** (feet)
1	0
2	0.02
3	0.02
4	0.02
5	0.02
6	0.02
7	0.03
8	0.03
9	0.04
10	0.04
11	0.03
12	0.03
13	0
14	0.02
15	0.12 (construction joint)
16	0.01

Lock 13

Intermediate wall
Monolith 25 - 6.5 ft from U/S joint

Top of lock wall elevation	592.0
Upper pool	583.0
Lower pool	572.0
Gage zero	568.7

Stage upper pool	14.46
Stage lower pool	6.75

Depth (feet)	**Loss** (feet)
1	0.01
2	0
3	0.01
4	0.01
5	0.01
6	0.02
7	0.01
8	0.02
9	0.02
10	0.02
11	0
12	0.03
13	0.07
14	0.07
15	0.09
16	0.12

Lock 13

Intermediate wall
Monolith 16 - 13 ft from U/S joint

Top of lock wall elevation 592.0

Upper pool	583.0
Lower pool	572.0
Gage zero	568.7

Stage upper pool	14.46
Stage lower pool	6.75

Depth (feet)	**Loss** (feet)
1	0.01
2	0
3	0.01
4	0.02
5	0.02
6	0.02
7	0.02
8	0.02
9	0.02
10	0.01
11	0
12	0.02
13	0.04
14	0.05
15	0.04
16	0

Appendix D
Field Logs for Lock and Dam 15 Loss Measurements

Lock 15

Land wall
Monolith 25 - 14 ft from U/S joint

Top of lock wall elevation	568.25
Upper pool	561.0
Lower pool	545.0
Gage zero	542.2
Stage upper pool	18.66
Stage lower pool	6.66

Depth (feet)	Loss (feet)
1	0
2	0.01
3	0.01
4	0
5	0
6	0
7	0
8	0
9	0
10	0
11	0
12	0
13	0
14	0
15	0
16	0
17	0.01
18	0.01
19	0

Lock 15

Land wall
Monolith 15 - 15 ft from D/S joint

Top of lock wall elevation	568.25
Upper pool	561.0
Lower pool	545.0
Gage zero	542.2
Stage upper pool	18.66
Stage lower pool	6.66

Depth (feet)	**Loss** (feet)
1	0
2	0
3	0
4	0
5	0.01
6	0.02
7	0.01
8	0.02
9	0.02
10	0.03
11	0.02
12	0.04
13	0.04
14	0.03
15	0.03
16	0.01
17	0.07
18	0.01

Lock 15

Land wall
Monolith 13 - 4.8 ft from D/S joint

Top of lock wall elevation	568.25
Upper pool	561.0
Lower pool	545.0
Gage zero	542.2
Stage upper pool	18.66
Stage lower pool	6.66

Depth (feet)	Loss (feet)
1	0
2	0
3	0
4	0
5	0
6	0
7	0
8	0
9	0
10	0.03
11	0.01
12	0.01
13	0.01
14	0.01
15	0.02
16	0.05
17	0
18	0

Lock 15

Intermediate wall
Monolith 8 - 3 ft from D/S joint

Top of lock wall elevation	568.25
Upper pool	561.0
Lower pool	545.0
Gage zero	542.2
Stage upper pool	18.66
Stage lower pool	6.66

Depth (feet)	Loss (feet)
1	0.01
2	0.02
3	0.03
4	0
5	0.01
6	0.01
7	0
8	0
9	0
10	0.01
11	0
12	0.01
13	0.01
14	0.01
15	0.02
16	0.01
17	0
18	0

Lock 15

Intermediate wall
Monolith 16 - 10.5 ft from D/S joint

Top of lock wall elevation	568.25
Upper pool	561.0
Lower pool	545.0
Gage zero	542.2
Stage upper pool	18.66
Stage lower pool	6.66

Depth (feet)	**Loss** (feet)
1	0
2	0
3	0
4	0
5	0
6	0
7	0
8	0
9	0
10	0.09 (construction joint)
11	0.01
12	0.01
13	0.02
14	0.01
15	0.01
16	0
17	0
18	0

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13. ABSTRACT *(Maximum 200 words)*

A multifaceted study was performed as part of the Upper Mississippi River - Illinois Waterways Navigation Study (UMR-IWW) to gather unknown or previously estimated data to assist with studying the deterioration and loss of concrete from lock walls. This effort revolved around physically monitoring barge traffic in lock chambers with time-lapse video equipment as well as measuring the actual losses from lock wall surfaces to determine the critical parameters needed for the model. Time-lapse videotape equipment was installed at three lock chambers in the UMR-IWW navigation area. The physical data collected from the videotapes assisted with determining barge velocities, the number of barge impacts on lock walls, chamber pool fluctuations, and the general operating characteristics of locks during the winter months. Measurements of lock walls were also made at four lock chambers to determine the depth of deterioration and typical deterioration patterns that exist at each lock. From this information, a model to predict the deterioration of concrete in lock chambers can be developed and implemented.

14. SUBJECT TERMS

Abrasion	Deterioration	Lock walls	Time-lapse
Barge	Freeze-thaw	Physical data	Velocity
Concrete	Impacts	Pools	Videotape
Data collection	Lock chambers	Saturation	

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